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HOWITT, J. E.

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FUNGUS AND BACTERIAL DISEASES OF VEGETABLES

By J. E. HOWITT, *Professor of Botany*;

D. R. SANDS, *Lecturer in Botany*;

D. H. JONES, *Professor of Bacteriology*.

INTRODUCTION

The object of this bulletin is to furnish all who are interested in the growing of vegetables with information which will enable them to identify the more common fungus and bacterial diseases of vegetables and to apply intelligently the treatments which experience has proved to be the most effective in each case.

In a bulletin of this nature it has been thought wise to include the bacterial with the fungus diseases, in order to place in the hands of the grower a complete and convenient manual of all the more important diseases of vegetables.

The majority of the diseases of vegetables are what are known as fungus and bacterial diseases. It is important that those having to deal with them should understand fully the cause of such diseases in order that they may apply intelligently remedies for their control.

THE NATURE OF FUNGUS DISEASES

Fungus diseases are caused by plants known as fungi. These plants, unlike ordinary flowering plants, have no green coloring matter (chlorophyll) and are unable, therefore, to manufacture their own food. All their nourishment must be obtained from decaying animal or vegetable remains or from living plants or animals. Those fungi which derive their nourishment from living plants in so doing injure them in various ways, and thus give rise to what are known as fungus diseases.

The bodies of fungi which cause plant diseases are usually extremely small and very simple, consisting of very fine, delicate, thread-like structures (hyphae), some of which become modified and produce reproductive bodies called spores, which may be considered similar to the seeds of flowering plants. Sometimes the fungus threads live upon the surface of the plants and obtain their nourishment by sending down little suckers (haustoria) into the cells below. Most frequently, however, they live within the plants, either in or between the cells. Two kinds of spores are usually produced—thin-walled summer spores, which spread the disease during the growing season, and thick-walled resting or winter spores, which serve to carry the disease over the winter. Spores are scattered by various agen-

cies, chief among which are wind, water and insects. On coming in contact with a suitable host plant, they send out little threads (germ tubes), which enter the plants through the little pores on the leaves (stomata), through the skin or through wounds. Once within the plant, these little threads grow rapidly, drawing their nourishment from the cells of the host plant and setting up a diseased condition.

Generally speaking, in combating fungus diseases methods of prevention only are practicable, as once a fungus is within the plant nothing can be done to destroy it. Care should be taken to keep the crops in a healthy growing condition and free from injury by insects. Unthrifty plants and those attacked by insects are more subject to fungus diseases than healthy ones. Rotation of crops should be practised, so that the winter spores left in the soil may not infect the next season's crop. Weeds should be destroyed, as they frequently harbor fungi. Diseased crop refuse should be burned and not thrown on the manure heap. Fresh manure should be avoided, as it frequently contains living spores of parasitic fungi.

Intelligent and thorough spraying with Bordeaux or other fungicides will do much to prevent the spread of fungus diseases. It should be kept in mind, however, that spraying is done not to cure, but to prevent disease. In other words, the object of spraying is to cover the surface of the leaves, fruits or other parts of the plant with a substance poisonous to the spores of fungi, in which they cannot grow and penetrate the plant. Spraying, therefore, in order to be effective, must be timely and thorough. The spray mixture must be on the plant before the spores reach it, and the surface of the leaves, fruit and other parts of the plant must be covered so completely that there is not the smallest space on which a spore can germinate.

THE NATURE OF BACTERIAL DISEASES

Bacteria are microscopical fungus plants. They are the smallest forms of life known. Their average size is about $1/10,000$ of an inch. They multiply very rapidly under favourable conditions, so that one may become anywhere from ten millions to twenty millions in twenty-four hours. There are many kinds of them. Most kinds are useful, particularly in the soil, where they prepare the plant food for the growing crops. Some of them are injurious, however, and among these are those that cause the bacterial diseases of vegetables. When these get into the growing plants, either through wounds made by insects and cultivators or through the water pores or breathing pores of the plant, they feed on the plant juices and bring about a diseased condition such as a soft rot, canker or wilt.

Generally speaking, spraying, which is so useful in checking or preventing fungus diseases, is of little or no use in controlling bacterial diseases. This is because the bacteria which cause disease get inside the plant and the spray only reaches the surface, and therefore does not come in contact with the bacteria. Poison sprays, by killing insects, help to prevent the spread of those bacterial diseases the germs of which are carried by insects.

In preventing or controlling bacterial disease of plants care should be taken, first, to use only seed that has been obtained from crops where there has been no disease; second, whenever a plant in the growing crop is found to be suffering from a bacterial disease, the plant, where practicable, should be carefully removed and burned, because as long as it is left standing in the crop it serves as a centre from which the germs of the disease may be carried to healthy plants by insects, slugs, caterpillars, cultivators or the hands of operators; third, refuse from diseased plants should not be ploughed into the soil or thrown on the manure pile or compost heap, but should be carefully gathered and burned; because the disease bacteria in such refuse are liable to live over winter and cause trouble next season.



Asparagus Rust.

1. Attacked stem showing spore clusters.
2. Cluster-cup form.
3. Spores from cluster-cup.
4. Spores from summer stage. (*urediniospores*).
5. Resting or winter spores. (*teliospores*).

ASPARAGUS RUST

This disease is often seen in Ontario. Before the advent of varieties of asparagus resistant to rust it frequently severely injured asparagus in many parts of the Province.

Symptoms. There are three distinct stages of this disease. The first is known as the cluster cup stage or the spring form. It appears on the young shoots shortly after they come above the ground. On these are seen orange-yellow or greenish yellow cup-shaped pustules grouped in oval clusters. This stage of the rust is seldom noticed by asparagus growers. The second or summer stage is the one that is usually first noticed and called by them the red rust on account of the elongated reddish-brown pustules which are seen breaking through the skin on the stem. The third stage of the disease is seen towards fall or whenever the vitality of the asparagus plants is reduced. It is known as the black rust or winter rust and is characterized by elongated black lines which replace the reddish brown pustules of the red rust stage.

Cause. The fungus which causes asparagus rust is *Puccinia asparagi* D.C. It produces four kinds of spores which take a direct part in its life history. In the elongated black lines of the black rust or winter rust thick-walled two-celled dark brown spores are produced. These are known as winter spores (*teliospores*). They pass the winter on the old asparagus tops

and refuse. In the spring they germinate and each one may produce eight very minute spores which we may call spring spores (basidiospores). These are scattered by the wind about the time the young asparagus shoots are emerging from the ground. They infect these young shoots and give rise to the cluster-cup stage of rust. In each of the cup-shaped pustules on the young shoots are produced chains of thin-walled orange-colored spores known as cluster-cup spores. These cluster-cup spores are scattered by the wind and infect the stems of asparagus plants giving rise to the red rust or summer rust stage of the disease. In the elongated reddish-brown pustules of this stage are produced numerous thin-walled oval orange-colored spores known as red rust spores or summer spores (urediniospores). These serve to spread the rust during the growing season. Moisture is essential for the spread of the rust, heavy dews having more influence on its spread than rain.

Control. Grow varieties of asparagus which are known to be rust resistant. Martha Washington and Mary Washington are two commercial varieties which are resistant to rust. If a grower desires to secure a resistant variety of asparagus and is not sure where to obtain it, he should consult the agricultural representative in his county or the Department of Horticulture, Ontario Agricultural College. The various gardeners' journals print advertisements of reliable firms that sell desirable rust resistant strains of asparagus.

It is very difficult indeed to prevent rust from developing on varieties which are susceptible to it. Such varieties should be put as far away from all windbreaks as possible. The rows should be planted in the direction of prevailing winds and far enough apart to permit air to circulate freely among the branches so that the excessive moisture on the plants from dew and rain will dry up quickly. Do not let any plants, even wild ones, mature during the cutting season. Late in the fall when growth is over cut out and burn the old plants. Destroy any wild asparagus plants that may be growing in the neighbourhood of the asparagus bed. Spraying with Bordeaux mixture and dusting with sulphur have been tried and fair results obtained in the United States. Spraying or dusting however, is a difficult and costly undertaking and it is doubtful whether it would pay here in Ontario.

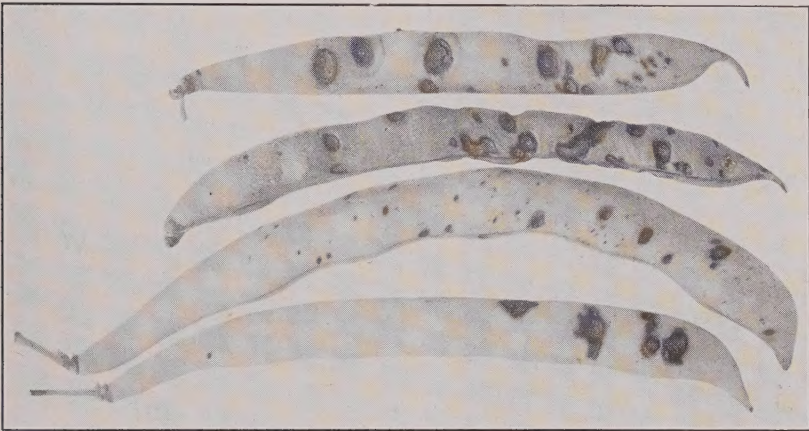
BEANS

ANTHRACNOSE OR POD SPOT. This is the commonest and most serious disease to which beans are subject. In wet seasons it causes great loss by destroying both garden and field beans.

Symptoms. Pods, seeds, leaves and stems are affected. On the pods sunken, reddish-brown or black spots, usually with rusty brown borders, are seen. In the centre of these spots pinkish masses may be noticed frequently. Affected seeds show dark brown or rusty discolored spots. These are often very minute. On the leaves the chief symptom is the brown and rusted appearance of the main veins underneath. Sometimes these appear as if cut or eaten out by the fungus. Occasionally small holes appear in the leaf, due to the destruction of the veins by the fungus. On the stems, rusty brown, elongated spots are sometimes seen. Occasionally these spots are so deep as to cause the stem of the leaf to break at this point.

Cause. This disease is caused by the fungus *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav. This fungus passes the winter chiefly as dormant fungus threads (mycelium) in infected seed and poss-

ibly to some extent as spores on the seed. It is also known to winter over on diseased material left in the field and in beanstraw. This fungus however, does not live long in the soil when separated from its host. The seed can be infected only through the pod, that is the fungus threads (mycelium) penetrate through the tissues of the pod into the seed beneath so that pods that are spotted with anthracnose contain infected seed while those that are free from spots contain non-infected seed. When infected seed is sown in the spring the fungus threads inside become active and grow and the first crop of spores of the season is produced on the seed leaves (cotyledons) of the seedlings. From these they spread to the true leaves and stems and later to the developing pods. The spores of this fungus are held together on the surface of the affected parts by the gelatinous nature of the spore-coat and are only scattered when the beans are wet with rain or dew which dissolves the gelatinous substance by which the spores are glued to the surface of the pod.



Bean Anthracnose Pods, showing the spots characteristic of the disease.
(Courtesy of the Department of Plant Pathology, Cornell University).

Control. Use non-infected seed. Such seed can be secured by selecting it from disease-free pods. This method is quite simple and satisfactory for small garden plots of beans and for a seed plot from which to secure a seed supply of field beans for the following year. In the fall of the year after the beans ripen gather enough disease-free pods to supply the seed necessary for the following season. Clean seed alone however, is not enough to insure a healthy crop. It must be planted far enough from infested fields so that spores will not be carried from the diseased plants to the healthy plants grown from the clean seed. If Anthracnose is bad, beans should not be planted on the same ground oftener than once in three or four years. Beanstraw should never be used for manure with the bean crop. Do not work among the beans when they are wet with rain or dew. Some varieties of beans are much more resistant to pod spot than others. These resistant varieties can often be used to advantage. Wells Red Kidney, White Imperial, Perry Marrow are varieties of dry beans which show a marked resistance to pod spot. There are also a number of varieties of wax and green pod, bush and pole beans which are more or less resistant. Burpee's stringless green pod has shown marked resistance in field trials here at Guelph for the past four years.

BACTERIOSIS OF BEANS—BEAN BLIGHT

(Phytopomonas phaseoli) Erw. F. Smith, S.A.B.

This disease produces spots or patches on leaves, stems, pods and beans within the pods, somewhat similar in appearance to those caused by anthracnose. It may also produce a wilt when the vascular system of the plant is invaded by the bacteria.

Symptoms: On Leaves. The disease first appears as minute dark green, water-soaked spots around point of infection, which, under favourable conditions, increase in size to a quarter of an inch or so, and, if they are close together, they may join up and thus form large patches. If the plants are juicy a light amber coloured sticky fluid is liable to ooze out on to the surface of the diseased parts. This dries and forms a thin scale on the surface. The middle portion of the diseased areas dies and turns brown. The dead tissue becoming dry and brittle in the sun or soft in the rain, is liable to break away, thus leaving the foliage in a ragged condition, torn around the edges and full of holes. If the leaves are infected when they are young they are liable to be distorted.

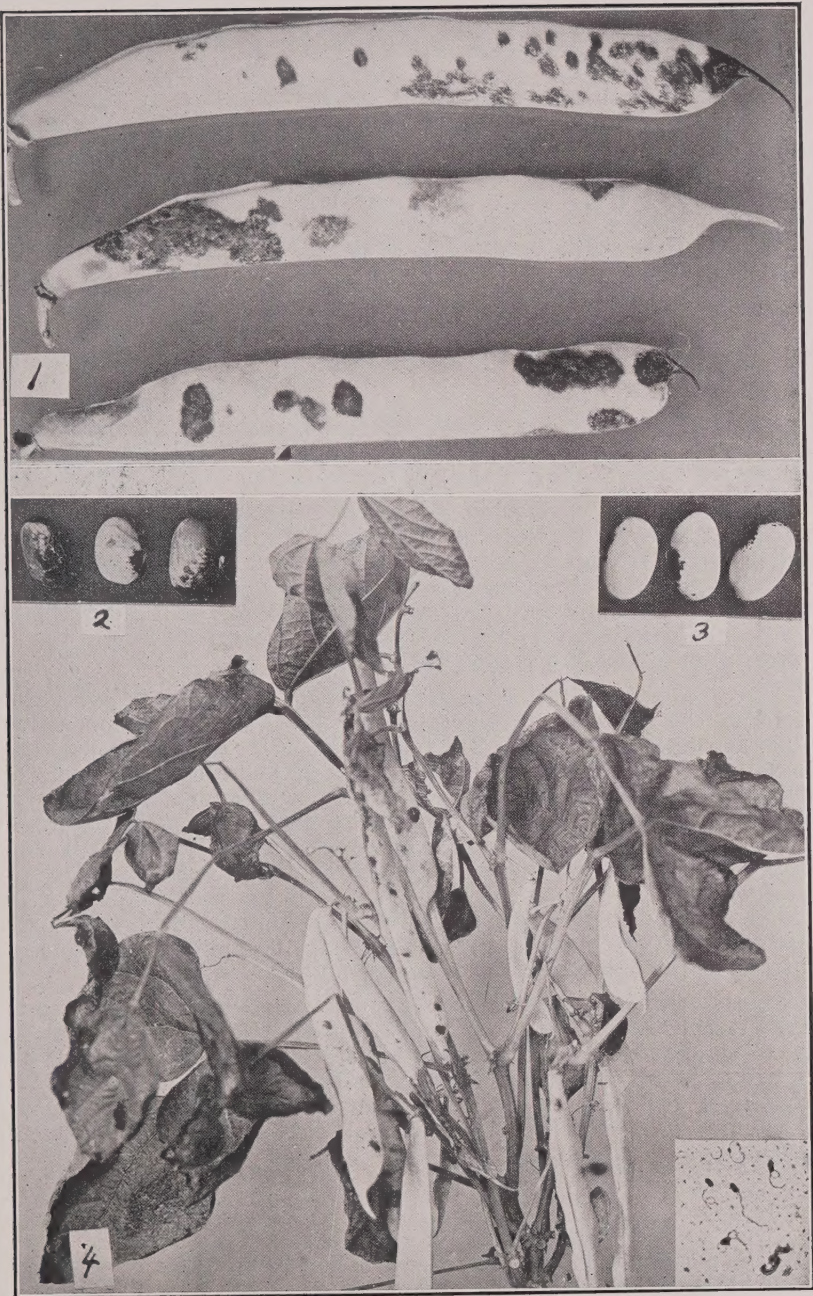
On Stems and Leaf Petioles. The disease appears first as water-soaked areas which later develop a brown cankered appearance extending up and down and often girdling the part. These areas later become dry and brittle so that the stems or petioles affected are easily broken at these points by wind or cultivator or other disturbing agent. Much defoliation is liable to occur in this way.

On Pods. The disease first shows as small water-soaked patches which, under favourable conditions, rapidly enlarge and develop a somewhat blister-like reddish brown, cankered appearance, not sunken in the middle as in case of anthracnose, but frequently slightly raised above the level of the surrounding healthy tissue, and more or less irregular in outline.

On Beans Within the Pod. The disease may develop as a result of the bacteria working in from diseased pods. If the bean seeds are thus infected when they are young, they do not mature but become more or less shrunk and discoloured brown. If the bean seeds are fully grown and nearing maturity before the bacteria reach the interior of the pods, they usually become smeared with the gummy exudate from the diseased pods which may dry on them like a coat of varnish. In this dried exudate the bacteria may remain alive for several years. Where such contaminated seed is sown it produces diseased plants that soon die.

On Cotyledons of seedlings grown from diseased or contaminated seed, brown or amber coloured canker-like patches are apt to develop from the renewed activities of the bacteria that have remained dormant over winter on the seed. From this infection of the cotyledons the bacteria readily gain entrance to the vascular system of the plant, clog it up, and so cause the plant to wilt and then die.

Cause. *Phytopomonas phaseoli*, the species of bacteria that causes this disease is a short rod about one ten thousandth of an inch long. It gains entrance to the various parts of growing bean plants mostly through the stomates (breathing pores) and through injuries made by insects, cultivators, wind and other agencies. On gaining entrance to the plant it feeds on the plant juices, rapidly multiplies and spreads from its point of entrance into the surrounding tissues along the intercellular spaces, causing the discolouration and cankered condition above described.



Bacteriosis of Beans. (Original).

1. Diseased pods.
2. Diseased beans from diseased pods.
3. Healthy beans.
4. Bean plant badly affected with bacteriosis in foliage and pods.
5. *Ps. phaseoli*, the cause of the disease.

Control. Use for sowing only those seed beans known to be free from disease. Select healthy bean pods in the field from which to obtain disease-free seed.

Bean seed treatments with chemicals, hot water or dry heat are not effective in disinfecting the seed, and moreover they are apt to cause considerable direct injury to the seed.

Some authorities recommend the use of seed beans that have been stored for two or three years for giving blight free plants. The writer, however, has found the bacteria that cause the disease alive on beans taken from diseased pods that had been stored in a dry laboratory for four years.

Bean straw from crops where the disease has been present, should be carefully gathered and burned.

BEAN MOSAIC

This disease is frequently seen in Ontario. It sometimes causes very serious loss especially to pea beans. Certain strains of pea beans have had to be discarded on account of their susceptibility to this trouble. Wax beans and green pod bush beans are also subject to Mosaic.

Symptoms. Badly affected plants are stunted and sickly yellow in colour with the leaves puckered and mottled with an alternate light greenish-yellow and dark green patches. The diseased plants usually remain alive until the end of the season. Those which are infected early in the summer rarely bear any seed though they sometimes continue to blossom until autumn. Those that do not contract the disease until late in the summer develop pods which are apparently normal.

Cause. No organism has been discovered to account for this disease. It is one of the so-called virus diseases, that is, there is a something in the juice of diseased plants which, for want of a better name, is termed a virus, which if transferred to healthy plants will cause the disease. So far as is known the virus which causes this disease is carried over the winter only in the bean seed. Infected seeds produce mosaic plants. In other words seeds from diseased plants produce diseased plants. The virus is spread from diseased to healthy plants by various insects and may possibly be spread from plant to plant upon implements and by the hands of workmen as it is known that it may be transferred in any manner that juice may be transferred from one plant to another. Once inside the plant it may spread to all parts of the plant including the pods and the seed.

Control. The use of the more resistant varieties of beans is the most practical method of avoiding loss from Bean Mosaic. The Robust Pea Bean is said to be one of the most resistant varieties. *Other varieties of beans which are resistant in various degrees to Mosaic are: Red Marrow, White Marrow, Long Pod. Keeney Rustless, Germain Black Wax, Michigan White Wax, Refugee Wax, Prolific Black Wax, Scarlet Flagolet and Red Valentine.

*Manual of Vegetable Garden Diseases by Charles Chupp.

BEAN RUST

This is a common but seldom a serious disease in Ontario. It is seen on all kinds of beans, especially pea beans.

Symptoms. Rust spots appear on all parts of the plant above the ground. They are however, usually most numerous on the under side of the leaves. The rust spots are distinctly circular, slightly raised. At first they are reddish-brown in colour, later in the season they turn black. They may be very numerous on the under surface of the leaves.

Cause. The fungus which causes bean rust is *Uromyces appendiculatus* (Pers.) Lev. This fungus produces red rust spores (urediniospores) and black rust spores (teliospores) on the lower surface of the leaves and other affected parts of the plant. It is carried over the winter chiefly as the teliospores on the old leaves and stems.

Control. The easiest way of avoiding this disease is by using the more resistant varieties. Pole Beans are more susceptible to rust than are bush varieties. Green Pod strains are less resistant than are those with wax pods. Nothing has been done in Ontario in regard to the selection of resistant varieties as bean rust has never been a serious disease in this Province. Experimental work carried on in Virginia has supplied us with the following lists of more or less resistant varieties:

Resistant varieties of pole beans: Marblehead, Tennessee Wonder, Brockton, Indian Chief, Everbearing.

Resistant varieties of bush beans: Hodson Green Pod, Early Refugee, Mexican Red, Golden Eye, Detroit, Hodson Wax, Wells Red Kidney, White Kidney, Yellow Eye.



Leaf of beet attacked by leaf-spot fungus (*Cercospora beticola*).

BEETS

LEAF SPOT. This disease is very common in Ontario but seldom causes serious injury to garden varieties. In some seasons it severely injures the leaves of sugar beets and mangels.

Symptoms. It is easily recognized by the small white or brown spots with purple margins which are scattered irregularly over the leaves. In the later stages of the disease these spots become ash-grey in colour. When they are very numerous the leaves wither and die. Sugar beets severely injured by this disease develop long crowns and are not desirable for sugar purposes.

Cause. This disease is caused by the fungus *Cercospora beticola* Sacc. The spores of this fungus are scattered by rain, insects, cultivating tools, workmen and wind. It passes the winter in the old infested refuse or on the seed. High humidity and temperature increase infection by this fungus.

Control. Plow under the old leaves deeply in the fall. Do not grow beets or closely related plants (Mangels and Swiss Chard) on the same ground oftener than once in two or three years. In small gardens rake up the diseased leaves and burn them or feed them to cattle. If the leaves of sugar beets or mangels are harvested and placed in the silo the fermentation will destroy the fungus. Spraying with Bordeaux every two weeks or ten days will control this disease but is seldom necessary.

CABBAGES

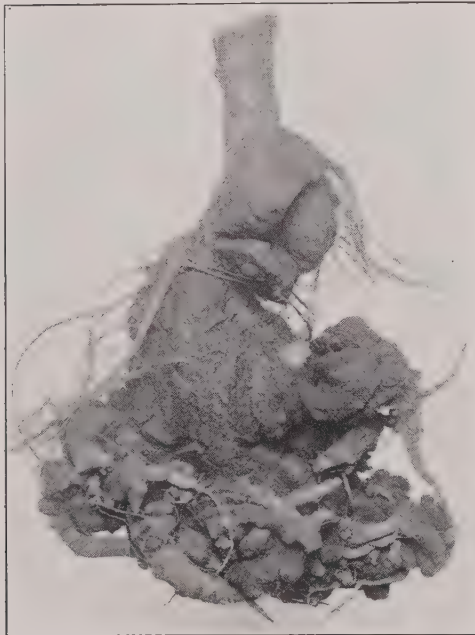
CLUB ROOT. This is a disease of cabbage, cauliflower, turnips, radishes and other members of the Mustard family (Cruciferae). It is a very troublesome disease in the Maritime Provinces and is occasionally met with in Ontario especially in market gardens in the vicinities of our larger cities.

Symptoms. Affected plants are noticed to flag or wilt markedly and if their roots are examined irregular thickenings and knob-like swellings are found upon them. These often reach the size of a man's fist. The tops of diseased plants develop very slowly. Affected cabbage and cauliflower plants form little or no head. Sometimes the plants are completely killed. Late in the season the diseased roots may rot.

Cause. This disease is caused by a slime fungus known as *Plasmiodiophora brassicae* Wor. This is a soil organism that may remain in the soil for several years. It is spread in seedling plants, in contaminated manure, on farm implements and on the feet of man and animals. It may be washed from high to low land by running water. Experiments have shown that this parasite does not thrive in soil which is highly alkali and that it does most damage in poorly drained acid soil. It is stated that the spores germinate and infection takes place readily only when the soil is warm and wet.

Control. The location of the seed bed is important. It should be so situated that it is not subject to being washed by water running down from higher ground above it. The position of the seed bed should be changed from time to time or the soil in it renewed or sterilized with live steam. Seedlings should be carefully inspected for any evidence of Club Root. If any infected seedlings are discovered the whole lot should be discarded as many of them will probably develop the disease after they are planted out. Corrosive sublimate has been found to be of considerable value in preventing the development of Club Root in seed beds in which the soil is infested. One ounce to 10 gallons of water is recommended for the prevention of Club Root in young cabbage plants. The first application should be made as soon as the plants are through the soil. Four or five additional applications

should be given at weekly intervals. Cauliflower plants are injured by such a strong solution of Corrosive sublimate but may be safely treated with 1 ounce of corrosive sublimate in 15 gallons of water. Good results have also been obtained by disinfecting the soil in seed beds with Uspulun. Care must be taken not to use contaminated manure. It is often wise to substitute commercial fertilizers for farmyard manure, especially in the seed bed. Fields should be kept as free as possible from weeds belonging to the Mustard family as they may harbor the disease. If a few diseased plants are found in the field they should be pulled and burned at once. If the soil becomes infested a rotation of crops should be practised. Plants belonging to the Mustard family should not be grown in such soils oftener than once in six or eight years. If it is impossible to follow a long rotation of crops and cabbages, cauliflowers or turnips must be planted on infested soil, a very liberal application of lime applied three to six months before planting is recommended. The amount of lime required will vary with different soils depending upon their acidity. From two to five tons per acre should be worked thoroughly into the soil. Such large quantities of lime are often undesirable especially if potatoes are in the rotation and should not be used if it is possible to grow cabbages, cauliflowers and turnips on disease-free soil. All refuse from a diseased crop should be burned. If it is necessary to feed diseased turnips or other roots they should be thoroughly boiled.



Club Root of Cabbage. (Original.)

BLACKLEG OF CABBAGE. This disease is not confined to cabbages but is seen also on cauliflowers, Brussels Sprouts, Swede turnips, Kohl rabi, kale, rape, radish and several other cultivated plants belonging to the mustard family. In this Province cabbage and cauliflower are the only crops which are severely affected by this disease.

Symptoms. Plants may show the disease in the seed bed or in the field. Near the base of the stem are seen oval, depressed, light brown cankers. These enlarge and girdle the stem. The affected tissues turn black and the stem and roots decay. The blackening of the base of the stem has led to this disease being called Blackleg. Light brown spots may also appear on the leaves. In the cankers on the stem and in the spots on the leaves, numerous black dots, (the fruiting bodies of the fungus) may be seen. Badly diseased plants may wilt. Sometimes the edges of the leaves turn bluish red in colour. If the stems and roots of the older plants decay the weight of the heads causes them to lean or fall over. Affected plants usually die in a comparatively short time but in damp soil they may live over for a long time and even form heads.

Cause. *Phoma lingam* (Tode) Desm. is the fungus responsible for this disease. It passes the winter as fungus threads (mycelium) in the seed and as spores and fungus threads on the seed, and with the cabbage refuse in the soil. This fungus remains alive in the soil as long as any particles of cabbage or cauliflower stalks are left intact. It is disseminated in soil or manure containing cabbage refuse. Spring freshets carry the spores over large areas of a field or from one field to another. It is also spread on cultivating tools and by insects. The fungus appears to require abundance of moisture before it will develop rapidly, as the severity of the disease appears to be in direct proportion to the amount of rainfall in the early summer.

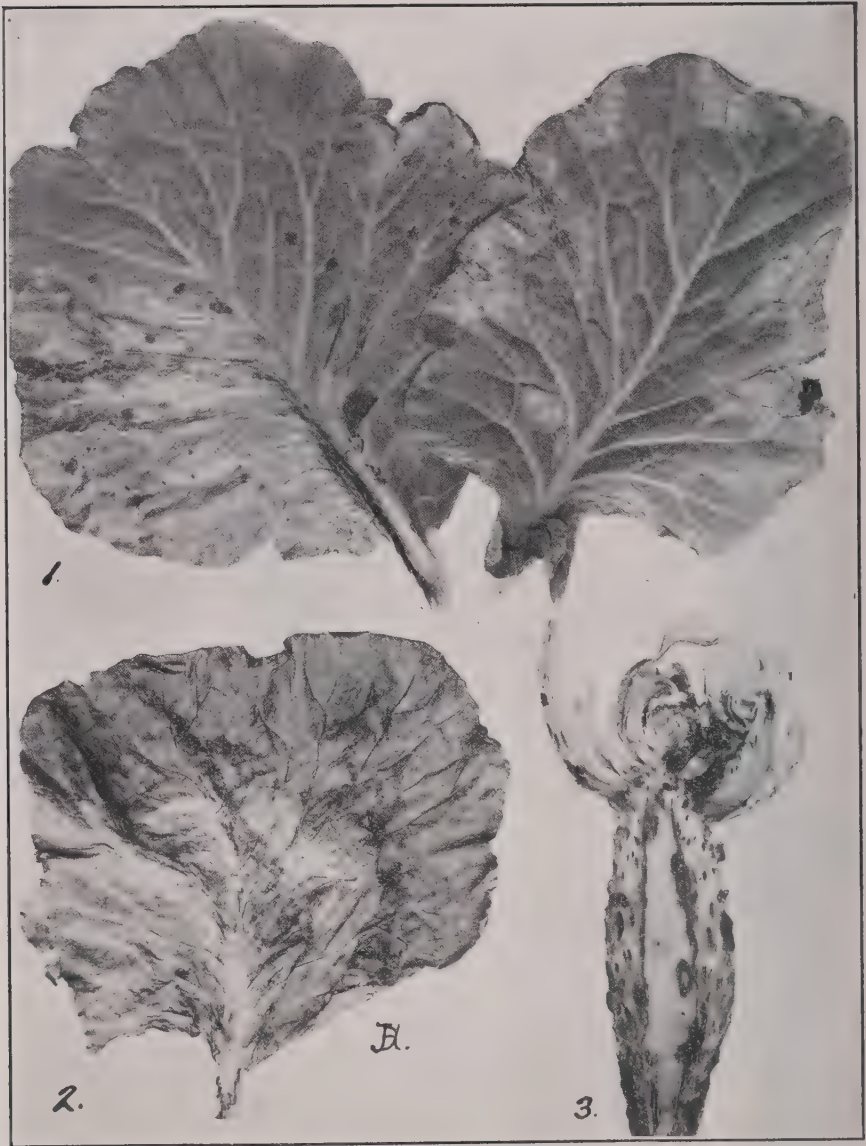
Control. Arrange a rotation of crops in which cabbage, cauliflower and other plants belonging to the mustard family are not grown on the same soil oftener than once in every four years. Rake up and burn the refuse from the diseased crop. Do not use seedlings from a seed bed in which there is any indication of Blackleg. Use non-infected seed. Such seed can now be secured from the Puget Sound section of United States where the disease does not normally occur. If the source of the seed is unknown it is advisable to treat it with corrosive sublimate or hot water. The directions for treating the seed with corrosive sublimate are as follows:—Use a solution of corrosive sublimate of the strength of 1-1000 by weight, which is prepared by dissolving one tablet in a pint of water, or an ounce of corrosive sublimate powder in 6 gallons of water. Place the seed in a cheesecloth bag. Do not fill the bag more than half full. Then immerse it in the solution for twenty to thirty minutes. After this rinse the seed thoroughly in clean water then spread it out to dry. Corrosive sublimate is a comparatively handy seed disinfectant but does not give as complete control as does hot water. This is due to the fact that while it will kill all the fungus which adheres to the outside of the cabbage seed, it can not kill the fungus threads (mycelium) within the seed. Seed may be disinfected by immersing the bags in water heated to a temperature of 122°F. for 30 minutes. When the bags are immersed in the water it should be kept stirred constantly and the temperature maintained at 122°F. by adding from time to time small amounts of boiling water. After the bags are removed from the hot water they should be dipped in cool water, after which the seed should be spread out to dry. This treatment is very effective but reduces the germination of the seed to a very considerable extent.



Bacterial Wilt of Crucifereae (Black Rot of Cabbage). (Original).
 1 and 2. Views in a cabbage plantation, showing numerous cases of the disease in all stages of development.

BACTERIAL WILT (BLACK ROT) OF CABBAGE AND CAULIFLOWER
(Phytomonas campestris) Pammel, S.A.B.

This disease is found attacking many cultivated cruciferous plants, including cabbage, cauliflower, kohlrabi, Brussels sprouts, broccoli, turnips, rape, kale and radish.



Bacterial Wilt of Crucifereae (Black Rot of Cabbage). (Original).

1. Cabbage leaves affected with the bacterial wilt or black rot. The lighter-shaded areas around the outer edge of the leaves are the diseased parts showing natural inoculation through the water pores on the edge of the leaves; the light-shaded areas were yellow.
2. The lighter shade part of the leaf near the base indicates the disease, and the blackened vascular bundles of the stem, where it is cut, indicates that the disease entered this leaf from the main stalk of the cabbage.
3. Cabbage stalk and stunted head; the blackened vascular bundles indicate that the disease was general throughout the plant. The leaf of Fig. 2 was taken from this plant.

Symptoms. In the leaves of growing cabbage or cauliflower plants, the disease most commonly appears as browned or yellowed triangular or irregular shaped, somewhat transparent patches working in from the outer edge. Inside these discoloured areas the veins or vascular bundles will appear as a blackened network. When the disease is far advanced in the leaf, a black discolouration of the vascular bundles in the midrib can be noticed, even through the thick white flesh that surrounds them. If such a midrib be cross-sectioned the infected vascular bundles will show as dark brown or black spots, and if a longitudinal section be made they will appear as dark brown or black streaks instead of white or pale yellow, as they should be if healthy.

Stems. When a leaf presenting the above symptoms is broken from the stem the vascular bundles showing on the leaf scar of the stem will appear as blackened dots, and if with the aid of a knife these infected vascular bundles be followed into the stem, the black discolouration may be found there in the bundles running up and down the stem. In advanced cases the surrounding tissue breaks down and cavities are produced.

Young Plants. If a plant contracts the disease as a seedling, or soon after being planted out, the chances are that it will either die soon or become a stunted, shrivelled, wilted specimen, producing no head, in the case of cabbage or cauliflower, and no bottom in the case of turnip.

Cause. The bacteria that cause this disease get established in the leaf veins and vessels of the vascular bundles where they multiply and clog up the passages, thus preventing the transmission of moisture and causing wilt.

One of the most common ways by which they gain entrance to the vascular system is through the water pores around the edges of the leaves. In the early morning, particularly in moist, cloudy weather, little dew-like droplets of water may be seen at the water pores around the edges of cabbage leaves and leaves of allied plants. This is water of transpiration which has not evaporated on account of the humidity of the atmosphere. Should the bacteria that cause this disease be around the edges of the leaves, having got there from contaminated soil or been deposited there by insects, slugs, caterpillars or other agencies, they will find conditions satisfactory for entering the waterpores, from which they invade the fine network of veins and slowly make their way through these channels until they reach the vascular bundles of the midrib, and later the stalk. Such progress may take several weeks. In moist weather development is much more rapid than in dry weather.

If the plants are well on towards maturity before such leaf infection takes place, losses will not be severe. The earlier the infection takes place the greater the damage to the plant.

Control. Should the disease be noticed among seedlings in the seed bed the diseased plants should be removed and burned. If they are not burned the bacteria within them are liable in many ways to get transferred to the healthy stock, and so the disease be spread instead of being checked.

Seedlings that show signs of the disease should not be planted out. It is not usually of much use simply to break a diseased leaf from what appears to be an otherwise healthy plant. If the disease is confined to the marginal areas of the leaf, entirely, then breaking off the leaf would prevent the rest of the plant from developing the disease. But should the vascular bundles in the midrib of the leaf at the point of its contact with the plant stalk, be discoloured brown or black we may take it for granted that the bacteria are already established in the vascular bundles of the stalk, in which case the whole plant should be destroyed.

Cabbage heads which on harvesting show blackened vascular bundles in the stalk close up to the head, should not be stored away but sold for immediate consumption. If such heads are stored away, the bacteria are liable to pass from the stalk to the vascular system of the leaves composing the head, and cause slow death to the tissues which then rot during storage.

Seed beds are often contaminated with the bacteria that cause this disease by having thrown onto them compost or manure on which diseased plants have been deposited to rot. While it is very doubtful that the bacteria enter the plant through the root hairs, any injury to the root or leaves that are near the ground may result in the establishment of the disease in the plant. Caterpillars and slugs crawling over such soil would be very liable to inoculate the plants growing there by crawling over and feeding on them.

Disinfecting Seed. Place seed in a cotton bag and suspend it for fifteen minutes in a solution of corrosive sublimate one part to one thousand parts of water; or in a formaldehyde solution of one part formalin (40 per cent. formaldehyde) to two hundred and forty parts of water. After treatment the seed should be dried without delay.

BACTERIAL SOFT ROT OF CABBAGE AND CAULIFLOWER

(See Bacterial Soft Rot of Vegetables)

CELERY

LATE BLIGHT OR SEPTORIA LEAF SPOT. This is the most common and destructive celery disease in Ontario. In wet seasons it is very severe and ruins large quantities of celery. It is not usually noticed by the grower until late in the season but a careful observer usually can find a little of it in the seed bed or in the field shortly after the plants are set out.

Symptoms. On infected leaves irregular brownish spots usually develop. In these may be seen numerous minute black specks, the fruiting bodies of the fungus, (pycnidia). When the disease is very bad however, on many of the leaves the characteristic spots may not develop but the whole leaf may be affected at once, become covered with minute black specks, dry and wither up. The lower leaves are almost always the first to show symptoms of the disease. The stems also are affected. On these are seen irregular rusty brown, somewhat water-soaked areas with the characteristic minute black specks. These rusty brown spots on the stems are often spoken of as rust by celery growers but are not true celery rust, but simply a manifestation of Late Blight on the stems. In storage diseased stalks decay due to secondary fungi and bacteria which follow the Blight fungus.

Cause. The causal fungus is *Septoria apii* (Br. & Cav.) Rostrup. This fungus produces numerous spores in the little black specks (pycnidia) embedded in the skin of the diseased leaves. When the plants are wet with rain or heavy dew these spores are discharged and spread by means of water, wind, insects, implements, men and horses. The fungus lives over winter in the diseased leaves and stems left lying on the field and in the seed-beds.

Control. Spraying with Bordeaux or dusting with copper-lime dust is the most reliable means of preventing this disease. The liquid Bordeaux has given the best results in our experiments here at the College but some growers secure satisfactory results with copper-lime dust applied frequently with high pressure.

The directions for spraying celery with Bordeaux are as follows: Give two applications when the plants are still in the seed bed using Bordeaux mixture of the strength of 3 pounds of bluestone and 6 pounds of hydrated lime to 40 gallons of water. The first application should be made when the plants are from two to three inches high and the second application given a short time before setting the plants out in the field. The field spraying should be started a week or ten days after the plants are set out. For the field applications use Bordeaux mixture of the strength of 4 pounds of copper sulphate, 8 pounds of hydrated lime and 40 gallons of water. Applications should be made at an interval of a week or ten days during the season. The wetter the weather the greater the number of applications that will be required. When the plants are small 40 gallons of the spray mixture will be sufficient for an acre but when the plants are



Late Blight of Celery.

(Courtesy of the Department of Plant Pathology, Cornell University).

large it will require two or three times this much. It is very important that the Bordeaux should be applied under high pressure. The sprayer should be rigged with three nozzles to each row, one from the top and one from each side. Late Blight spreads most rapidly during wet weather. It is therefore important to see that the Bordeaux is on the plants before rain comes rather than after.

The directions for dusting celery are as follows: Use 20 per cent. Copper-lime dust. Give two applications as described above while the plants are still in the seed bed and repeat at intervals of from 3 to 10 days after the plants are set out in the field. In very wet weather it may be necessary to apply the dust as often as twice a week. The best results from dusting are secured by using liberal quantities of dust and applying it under high pressure.

Other precautions which should be taken: Rake up and burn the diseased leaves and stalks. Plant celery so far as is possible on well drained land. Do not cultivate celery when the plants are wet and in cultivating take care not to get the soil into the crowns of the young plants. Rotation of crops is an effective means of preventing this disease as the causal organism is chiefly carried from year to year in the crop refuse in the soil, but it is not always practical under ordinary celery growing conditions. It is not advisable to attempt to store for any length of time celery affected with late blight. Before such celery is placed in storage the blighted leaves and stems should be stripped off. Those who grow large quantities of celery depend chiefly on spraying or dusting for the prevention of this disease.

EARLY BLIGHT OR CERCOSPORA LEAF BLIGHT. This disease compared with Late Blight of celery is of comparatively little importance in Ontario. It is seen to some extent every year and occasionally in isolated fields here and there it does considerable damage.

Symptoms. The name "Early Blight" is misleading as this disease does not usually appear until later in the season than the so-called "Late Blight." Usually it does not appear until the plants are from 6 to 8 weeks old while Late Blight is often seen shortly after the seedlings come above the ground. Affected leaves are characterized by more or less circular spots grayish green in colour at first, then becoming brown and later ashy. Separate spots generally have well marked borders. When numerous they run into each other in irregular patches.

Cause. *Cercospora apii* Fres. is the fungus which causes this disease. This fungus produces numerous spores on the surface of the leaves when the weather is hot and wet after a period of drouth. These spores are spread from plant to plant by rain, wind and during cultivation. The fungus is carried over the winter as hardened masses of mycelium (sclerotial growths) in the tissues of the diseased leaves.

Control. The recommendations given for the control of Late Blight of Celery apply in all their details to Early Blight.

CELERY YELLOWS. This disease was reported as occurring in Ontario for the first time in 1924. In the United States celery yellows has caused serious loss to celery growers especially in the State of Michigan. It is recorded as being most serious on certain strains of golden self blanching celery. These are said to be more susceptible than white plume and other winter varieties.

Symptoms. These are very distinct. Affected plants are stunted with yellow or yellowish-white leaves. They usually die prematurely. The veins (vascular bundles) of the roots and heart are reddish-brown in colour.

Cause. This disease is caused by a species of *Fusarium*. This fungus is a soil organism being carried over in the soil from year to year. Land badly infested with it is said to be worthless for the growing of many of the finer strains of golden self blanching celery. On account of the serious losses which may be caused by this disease Ontario celery growers should be on the watch for it.

Control. In Michigan it has been found that this disease can be avoided by growing resistant strains of golden self blanching celery. Such strains have been developed in Michigan and if Ontario celery growing soils become infected with the fungus which causes yellows, it may be necessary to introduce these resistant strains into this Province, or to develop here in the Province other resistant strains.

BACTERIAL SPOT DISEASE OF CELERY

(*Phytophthora apii*) Jagger, S.A.B.

This disease occurs on all varieties of celery commonly grown.

Symptoms. It appears as rusty brown spots, irregularly circular in outline, that rarely exceed a quarter of an inch in diameter. The spots closely resemble those caused by the celery late blight fungus. The latter however can be distinguished from the bacterial disease by the presence of the minute black pycnidia of the fungus fruiting bodies.

Occasionally the spots are so numerous as to cause the death of many of the older leaves, but usually the injury consists in the disfiguring of the foliage and in a possible reduction in growth of the plants. The disease seems to be confined to the leaf blades, spots seldom, if ever, occurring on the stalks.

The *Causal Organism* gains entrance either through the stomates or by means of insect puncture.

Spraying with Bordeaux mixture is effective in controlling this disease.

BACTERIAL SOFT ROT OF CELERY

(See *Bacterial Soft Rot of Vegetables*)

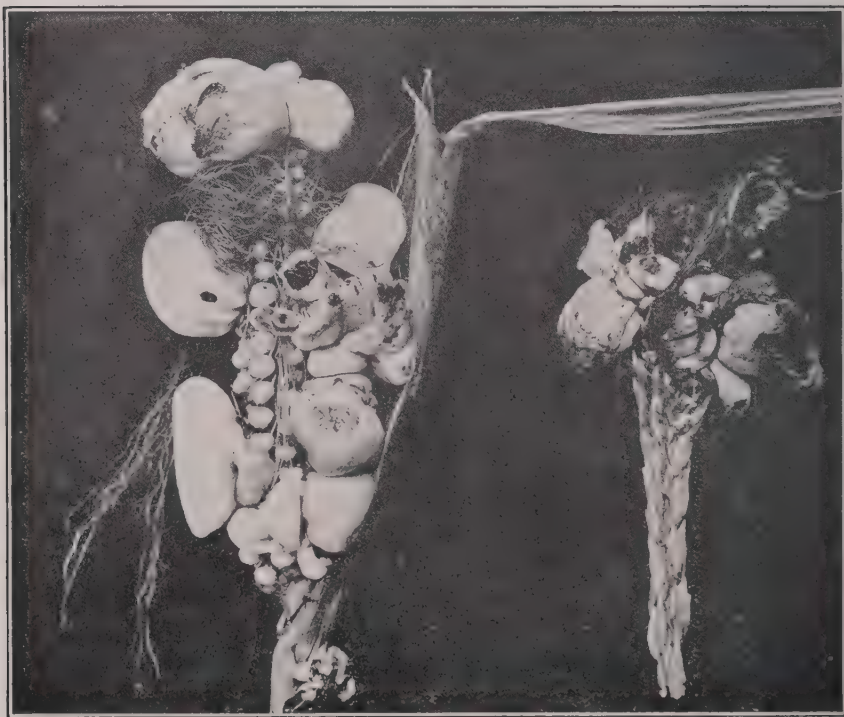
CORN

CORN SMUT. This smut is very frequently seen in Ontario and nearly everyone who grows any corn is familiar with it. The sugar or table corns seem to be especially susceptible to it.

Symptoms. Corn smut attacks the ears, stalks, leaves and tassels. It produces on the parts affected peculiar growths frequently spoken of as "boils." These "boils" are sometimes six inches or more in diameter. In the early stages they are green, later white and polished and finally they become dark colored and rupture, exposing a brownish black mass of powder consisting of millions of spores. Corn smut usually appears on the plants when they are about three feet high but on very susceptible varieties like Golden Bantam it is sometimes seen when the plants are less than a foot high.

Cause. The fungus which causes corn smut is *Ustilago zeae*, (Beckman) Unger. As soon as the "boils" mature and rupture, the spores are scattered by the wind and other agencies. In the soil or in manure they germinate and produce great numbers of secondary spores which may infect any of the tender growing tissues of the corn plants. Thus the smut is spread during the growing season. The fungus is carried over the winter as spores in the soil and in manure. These may be contaminated in various ways. The spores may be scattered by the wind or the spore mass may be left in the field, or thrown on the refuse or manure pile. It is believed that the spores of this fungus may not only live in the manure pile but that they may actually grow and increase in number in warm fermenting manure.

Control. Treating the seed with a seed disinfectant such as formalin or bluestone will not prevent Corn Smut as the fungus which causes it is carried over the winter as spores in the soil and in manure. Go through the field and burn all smut growths as soon as they appear as each "boil" when mature is a source of infection to the healthy plants around it. This of course is only practical when small areas of corn are grown. Avoid fresh manure with the corn crop as it is very likely to contain live smut spores. If possible practise a rotation of crops. The spores of this fungus will not live for many years in the soil and those which are in the soil cannot injure any other garden crop. After three or four years corn may be planted again with less danger as many of the spores will have lost their vitality by this time.



Corn Smut on Ear and Tassel. (About one-half natural size).



Bacterial Wilt of Cucurbits. (Original).

1. Bacterial wilt of cucumber.
2. Bacterial wilt of cucumber.
3. Bacterial wilt of squash.
4. Stained microscope preparation from the viscous slimy exudate of a vascular bundle of a wilting cucumber plant, showing the bacteria (*Erw. trachiphila*), ($\times 1000$ di).

CUCUMBERS

BACTERIAL WILT OF CUCUMBERS

(*Erwinia trachiphila*) Erw. F. Smith.

This wilt often causes serious losses to the growers of cucumbers, squashes, melons and other cucurbits. Whole fields or greenhouses of these plants are sometimes completely destroyed by the disease in a very short time,—one to three weeks.

Symptoms. The leaves and stems of plants suffering from this disease lose their turgidity and hang over limp and lifeless, thus presenting a badly wilted condition. They also lose their bright green colour and turn to a dull, dirty yellowish green. The fruit, when infected, becomes soft and appears somewhat water-soaked, and if squeezed will readily yield to pressure and often under such treatment the skin will rupture and a clear slimy liquid will ooze out. The flesh of diseased fruit is transparent and water-soaked in appearance. If a diseased stem be cut through, a gummy, slimy exudate will ooze out from the cut ends of the vascular bundles exposed on the cut surface. This slimy exudate will string out in strands when the cut surface is scraped with a knife or rubbed with the finger. This sliminess of the juice issuing from the vascular bundles is one of the most characteristic features of the disease, for a plant may wilt for lack of moisture and present an appearance something like a diseased plant. But if such a plant be cut and its juice expressed, this juice will be quite watery in consistency and not string out in slimy threads like the exudate from a diseased plant.

Cause. The bacteria that cause this disease are found almost entirely in the veins and vascular bundles of the diseased plant. Here they feed on the plant juice, grow and multiply, and choke up the vessels so that the passage of moisture from the roots to the leaves is interfered with, and thus the wilt develops.

The bacteria are carried from diseased plants to healthy plants almost entirely by the striped cucumber beetle, which after feeding on a diseased plant has its mouth parts covered with the bacteria, and these it carries to healthy plants which it subsequently feeds on.

Control. All diseased plants should be carefully removed and immediately burned. If they are allowed to lie around cucumber beetles and other insects will swarm about them, get themselves contaminated with the bacteria and spread the disease wherever they go.

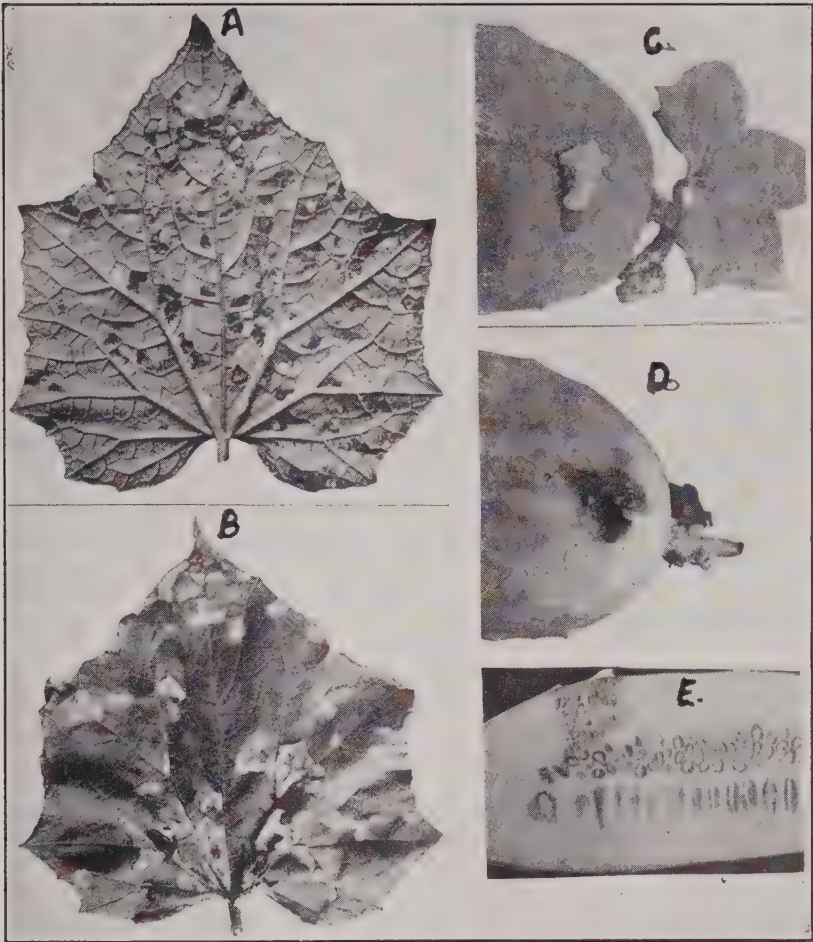
Biting insects, particularly the striped cucumber beetle, should be kept under control by spraying and hand picking.

ANGULAR LEAF SPOT OF CUCUMBERS

(*Phytophthora lachrymans*), Smith and Bryan, S.A.B.

While this disease has not, so far, caused heavy losses in Ontario, it occasionally gives trouble to cucumber growers.

Symptoms. Angular spots are developed on the leaves. At first the spots present a water-soaked appearance, then they become brown and dry and often drop out, giving the leaves a ragged appearance. Frequently the spots become confluent, thus resulting in large irregular holes. In the early stages of spot development a bacterial exudate is liable to collect in glistening tear-like drops on the lower surface of the leaves, during the night, which later dries whitish.



- A—Cucumber leaf eight days after inoculation with *Phytomonas lachrymans*. The bacterial exudate has dried down into white crusts.
- B—Cucumber leaf twelve days after spraying with *Phytomonas lachrymans*. Diseased tissue shrivelled and spots falling out.
- C—Green cucumber fruit photographed six days after inoculation with *Phytomonas lachrymans*. There is an exudate at the point inoculated while the remainder of the fruit is sound.
- D—Same as C. after twelve days; fruit ripening but still sound except at point of inoculation.
- E—Section of green cucumber fruit ten days after inoculation. Tissue decayed only in vicinity of inoculation.

(After M. C. Bryan)

Young stems and leaf petioles may be infected. They become softened in the infected area and crack open or bend over. Little drops of bacterial exudate are liable to appear on these diseased parts.

Fruit may also be infected, but unless other organisms gain entrance no general rot develops. The infected part slowly extends and is somewhat sharply differentiated from the surrounding healthy tissue. At first it is water-soaked in appearance, then turns whitish in the centre, dries and cracks. The characteristic exudate appears on the surface.

When female flowers become infected they do not set, but turn yellow, then blacken and dry up.

Cause. The bacteria that cause this disease gain entrance to the plants mostly through the stomates (breathing pores). They spread rather slowly through the intercellular spaces, crowding apart and crushing the tissue cells. They come to the surface with the exudate that oozes from the diseased parts, and from this location they may be washed by rain to nearby healthy plants, or carried by insects, cultivators or the hands of workers. The organism may be carried over winter on contaminated seed.

Control. Seed treatment—immersion for 5 minutes in corrosive sublimate 1-1000 has proved safe and effective; while treatment with 4 per cent. formalin proved injurious to the seed. Spraying plants with Bordeaux mixture checks spread of the disease. Keep insects in check.

MOSAIC OF CUCUMBERS. This disease is often seen in Ontario. It quite frequently causes very serious loss to cucumber growers. It is known by various names such as Mosaic, White Pickle, White-wart and Nubbin disease.

Symptoms. Plants may show symptoms of the disease in any stages of their growth. If seedlings are diseased the seed leaves (cotyledons) turn yellow. The leaves are mottled yellow and green and the plant is much dwarfed. There is little or no fruit set and the plant usually dies early. Generally plants do not show symptoms of the disease until they are passed the seedling stage. The peculiar yellow and green mottling of the foliage is the first symptom. The upper surface of the leaf is wrinkled and its edges curled downward. The affected leaves are dwarfed and the fruit does not set properly. If the fruit is affected it shows alternate irregular yellow and green spots, the latter being raised on wart-like projections.

Cause. This is another of the so-called virus diseases. The virus which causes it is not carried over in the soil or in the seeds of the cucumber or other cultivated vegetables. It has been demonstrated however, that it can live over the winter in the seed of the Wild Cucumber (*Echinocystis lobata*) and in the perennial roots of the milkweed, pokeweed and ground cherry. Aphids and the striped cucumber beetle serve to transmit the virus from diseased to healthy plants. It may also be transferred by rubbing together healthy and diseased leaves until there is bruising, or by other methods in which the plant sap may be transferred from a diseased to a healthy vine.

Control. No entirely satisfactory control measures have been devised. Spraying or dusting for the eradication of insects as suggested for the control of Bacterial Wilt is recommended. Wild cucumber, milkweed, pokeweed and ground cherry growing in the neighbourhood of the greenhouses and cucumber fields should be destroyed if possible. When diseased plants are noticed in the greenhouses they should be pulled up by the roots, carefully removed and burnt. If they are large and entwined with other plants pull them up by the roots and leave on the trellis so that the disease will not be spread by bruising healthy plants while removing them.

POWDERY MILDEW OF CUCUMBERS. This mildew is seen on squash, cucumbers and melons. In Ontario it is seldom of any importance in the field but sometimes becomes troublesome on cucumbers grown under glass.

Symptoms. Circular powdery spots are seen on the leaves and young stems. At first the tissue of the spots remains normal but finally turns brown and dried. In severe attacks the leaves may be killed. If all the foliage of the vine is covered with mildew the plant is weakened, has a yellowish colour and most of the fruit is rendered useless.

Cause. *Erysiphe cichoracearum* D.C. is the name of this mildew. This fungus produces two kinds of spores, summer spores (conidia) which are produced in enormous quantities in chains on the surface of the leaves and which give to the spots their powdery appearance. These summer spores serve to spread the fungus during the growing season. The second form of spores known as ascospores are produced in little black fruiting bodies (perithecia) on the surface of the leaves and petioles. They serve to carry the fungus over from season to season.

**Control.* This mildew can be prevented by dusting with sulphur or spraying with Bordeaux at intervals of a week or ten days. Sulphur dust is most effective for combatting powdery mildew in greenhouses. Sulphur dusting materials containing fifteen to twenty per cent. free sulphur are as effective as high grade dusts containing sixty to ninety-five per cent. free sulphur, and are safer, cheaper and therefore preferable. E. F. Guba states that dust should be applied at the rate of about 5 to 6 pounds to a house 280x40 ft. Bordeaux mixture of the strength of 1 pound of copper sulphate, 2 pounds of hydrated lime and 40 gallons of water can be safely used. Experiments have shown that if greenhouses are fumigated with hydrocyanic acid gas when Bordeaux is present on the leaves foliage injury may result.

*"Control of Cucumber Powdery Mildew in Greenhouses" by E. F. Guba, *Phytopathology*, Volume 18, No. 10, October 1928.

ANTHRACNOSE OF CUCUMBERS, SQUASH AND WATERMELONS. This is a disease which is frequently seen in Ontario, especially on cucumbers. It is seldom serious in the field but occasionally becomes very severe on cucumbers grown under glass.

Symptoms. On the leaves of affected plants brown dead circular spots are seen. These are frequently very numerous so that the whole leaf is destroyed. On the stems elongated light brown areas are observed. On affected fruit especially on the watermelon, water soaked sunken spots appear. These often have pink centres.

Cause. Anthracnose is caused by the fungus *Colletotrichum lagenarium* (Pass.) E & H. This fungus remains alive in the old diseased tissue in the soil in the field or in the greenhouse. It is also known to be carried over in and on the seed.

Control. No satisfactory control measures have been discovered. As the fungus lives over at least one season in the diseased plant refuse left in the soil, a rotation of crops is essential. Seed treatment is also recommended. This consists of dipping the seed in corrosive sublimate (1 ounce in 6 gallons of water) for 5 minutes then rinsing it thoroughly in running water and drying it. Spraying with Bordeaux mixture is also recommended. Spraying cucumbers under glass has not been profitable in the limited experiments carried on in this Province as the frequent and heavy sprayings required to control the disease have caused injury to the foliage and fruit.

DOWNY MILDEW OF CUCUMBERS. This disease is quite frequently seen in Ontario. It affects not only cucumbers but also squash, melons and pumpkins.

Symptoms. Irregularly shaped yellowish spots appear on the upper sides of the leaves. If a leaf is examined on the lower surface of the spots around the margin will be seen a downy fungus growth. If weather conditions are favourable these yellowish spots rapidly enlarge and finally the entire leaf withers up and dies.

Cause. *Peronoplasmopora cubensis* (B. & C.) Clint. is the fungus which causes this disease. This fungus spreads during the wet weather of the summer months by means of numerous spores produced on the under surface of the affected leaves. Just how this fungus passes the winter is not known. It is possible that it may survive the winter in greenhouses and spread to outdoor plants when the latter begin to grow. There is no evidence that it lives over in the soil outdoors.

Control. Spraying with Bordeaux mixture or dusting with copper lime dust will control this disease. Begin spraying or dusting early. In comparatively dry weather apply the Bordeaux or dust every ten days. If however, the weather is wet more frequent applications will be necessary. When the plants are young weak Bordeaux should be used (2 pounds copper sulphate, 4 pounds hydrated lime and 40 gallons of water). Later when the plants have formed runners the 4-8-40 formula can be used. In spraying or dusting it is important that both sides of the leaves should be covered with the fungicide. Frequent and heavy applications of Bordeaux applied to cucumber plants under glass may cause injury to foliage and fruit.



Downy Mildew of Muskmelon.
(After F. C. Stewart.)

LETTUCE

LETTUCE DROP. This is a serious disease of lettuce. It is frequently seen in Ontario on lettuce grown under glass.

Symptoms. The first symptom usually observed is the wilting of the outer leaves which droop and fall flat on the ground. All the leaves of the plant are soon affected in the same way and in a few days the entire plant is dead and lying flat on the ground. This sudden and entire collapse of the plants has given rise to the name "Drop". The disease usually appears on the stem near the surface of the soil as a soft water-soaked spot that spreads downward until the roots are decayed and upward until the bases of the leaves are affected.

Cause. The most common cause of leaf drop is the fungus *Sclerotinia libertiana* Fckl. This fungus forms innumerable black hard bodies termed sclerotia. These are a resting stage of the fungus and they serve to carry it over from season to season.

Control. Soil sterilization is the most important control measure. Either steam or formaldehyde may be used (See page 60). If a few diseased plants are seen in a bed they should be removed, taking care not to scatter any of the diseased tissue or sclerotia. After the plants are removed soak the vacant spot with a bluestone solution, 1 pound in 6 gallons of water. Keeping the top soil well stirred and as dry as good growth of lettuce will permit, helps to prevent the development of this disease. If possible a system of cropping should be so arranged as to alternate crops of lettuce with less susceptible vegetables such as radishes and tomatoes.

Two other fungus diseases, the Downy Mildew (*Bremia lactucae*, Reg.) and Leaf Spot (*Septoria consimilis* Ellis & Martin), are seen on lettuce to some extent in Ontario, but never seem to be serious enough to require any special attention when the crop is properly managed.

BACTERIAL ROT OF LETTUCE

- (1) *Phytomonas viridilivida*,
- (2) *Phytomonas vitians*, and
- (3) *Phytomonas marginale* by N. A. Brown, S.A.B.

Losses in the lettuce crop ranging from five per cent. to fifty per cent. or over, both in greenhouse and in field, have been traced to certain species of bacteria from the soil gaining entrance to the plant tissues.

Usually, however, if not invariably, such crops have been grown under abnormal atmospheric or soil conditions which have rendered the plants peculiarly susceptible to bacterial invasion and development. A stagnant, humid, warm atmosphere such as prevails in poorly ventilated greenhouses where the plants are excessively watered by spraying, or out in the open field during a prolonged warm, wet spell, or under the covers sometimes spread over the lettuce crop for night frost protection, has been shown to be particularly conducive of conditions in the plant tissues favouring bacterial invasion. Soils heavily treated with loose lightly rotted manure or compost have also been found to greatly favour the development of these lettuce rots.

Symptoms. In the lettuce rot caused by *Phytomonas viridilivida* the outer leaves of heads are mostly affected. The disease first appears as water-soaked areas surrounding point of inoculation. These areas converge and turn yellowish brown, and rot sometimes with a soft rot and other times with a dry rot, leaves shrivelling. The bacteria enter through the stomates (breathing pores), also through wounds made by insects and during handling. The disease is most in evidence after prolonged wet weather.

Control. Good results have been obtained from spraying infected plants with formalin, one pint to thirty gallons of water.

In the early stages of the lettuce rot caused by *Phytomonas vitians* the affected plants are a lighter green colour than healthy ones; later the head may show rot through the centre or only on top. A general wilting of the head may occur, with or without visible spots or rot. In some cases rotting is rapid; in other the heart remains sound while the outer encircling leaves are in a bad state of decay. The diseased plants are not firm in the soil, the stem is brittle and can be easily broken off at the surface or a little below the surface of the soil. In an early stage of the disease the stem, when cut across, shows a blue green colour; in a later stage it is brown. If the disease attacks a young plant no head will form. There are also cases where the stem remains sound and only the leaves are affected, these leaves having definitely outlined spots. In others the spots have coalesced, making a darkened mass of diseased tissue.

Control. As the worst cases of this disease have been found in land to which large quantities of only slightly decomposed manure and compost were added, making a very loose substratum for the roots, and thus producing plants of low resistance to bacterial invasion, it is recommended that only well rotted manure and compost be used on the land preceding the lettuce crop.

In the lettuce rot produced by *Phytomonas marginale* the symptoms are quite striking. At first there is usually a slight marginal wilting in more or less localized areas on leaves in the same whorl. These areas on the leaf margins may vary from mere specks to an inch or an inch and a half long, and may coalesce. On the older leaves the most common sign is wilting of the tips. The areas affected lop over and gradually become dry. The vascular tissues at this stage frequently show a distinct browning. In a few days the affected areas turn brown, tan, reddish and sometimes black. The tissues become dry and papery in texture. This disease does not usually extend down the entire leaf. It does not cause an extensive rot or soft decay of lettuce, but mars its appearance so that it is not saleable. Leaf lettuce is less liable to the disease than head lettuce.

Cause. Bacteria are found in large numbers in the more recently affected tissues. They gain entrance through the stomata when the leaves are in a weakened condition owing to cold, high humidity and excessive watering.

Control. Guard against high humidity and excessive watering. See that greenhouse is well ventilated.

ONIONS

ONION SMUT. This is a very injurious disease. It has become very prevalent and very destructive in several of the important onion growing districts of Ontario.

Symptoms. It appears only on onions grown from seed. It frequently destroys large numbers of the seedlings soon after they appear above the ground. The leaves of affected seedlings become curled and twisted and dark streaks show within the tissues. These streaks are filled with a dark brown powdery mass. Diseased seedlings that are not killed in the early stages, often die later or produce small, distorted bulbs with black streaks. If these black streaks are broken open they are found to be filled with a black mass of smut spores.

Cause. Onion Smut is caused by the fungus *Urocystis cepulae* Frost. This is a soil organism that may live in the ground for many years. It can infect onions only for a brief time during the development of the seedlings. The period of infection extends from the time of germination until the seedlings are in the first leaf. This is usually about two weeks. Once the seedlings have passed this stage the fungus cannot infect them. The spores of the fungus are carried from place to place on onion sets, by running water or in the soil adhering to implements, the feet of men and animals and the roots of other vegetables.

Control. A formalin solution applied when the onion seed is being sown has given excellent results in the control of this disease. The formalin is applied by means of a tank and drip attachment on the onion seeder. Numerous experiments have been conducted in the Pelee marshes and the best results have been obtained from the following solutions:

(1) Formalin, 1 pint to 15 gallons of water, applied at the rate of 150 gallons per acre; (2) Formalin, 1 pint to 10 gallons of water, applied at the rate of 100 gallons per acre. The latter solution cuts down to a minimum the amount of water that must be used and thus reduces the labour to a considerable extent. This is an important factor.

The formalin method is the one which is now extensively used by commercial onion growers and it is the only satisfactory treatment when large quantities of onions are grown. Those who grow but a few onions for their own use can prevent onion smut by sowing the seed in smut-free soil, and then transplanting the seedlings after they are passed the susceptible stage. They can also avoid it by growing their onions from sets instead of seed.

ONION BLIGHT OR DOWNY MILDEW. This is a very common disease of the onion in Ontario and in some parts of the Province it frequently decreases very materially the onion crop by destroying the leaves and thus reducing to a marked extent the size of the bulbs.

Symptoms. These are usually first noticed in late June or July. Affected leaves show peculiar violet-tinted areas due to the fuzzy spore-bearing portions of the fungus on the surface. They very soon become pale or yellowish in spots and collapse and break down. In severe attacks all the leaves in a field or patch are very soon destroyed. They are often however, quickly replaced by a new crop which in turn may be destroyed by the disease and from this second attack the onions do not usually recover.

Cause. This disease is caused by the fungus *Peronospora schleideni* Unger. Two kinds of spores are produced by this fungus, namely thin-walled summer spores borne on the minute, branched spore-bearing part of the fungus covering the surface of the attacked leaves, and thick-walled resting spores (oospores) formed in the tissues of the dead leaves. The

summer spores are freely scattered by wind during the summer and new leaves become infected. In this way the disease is spread very rapidly especially during damp muggy weather. Dead leaves containing the thick-walled resting spores lie on the ground during the winter and in the spring these spores germinate and give rise to the disease if onions are planted on the same ground again. The fungus also lives over as dormant fungus threads (mycelium) in the onion bulbs and sets.

Control. Rake up and burn the diseased tops as by so doing many of the resting spores will be destroyed. If possible practice a rotation of crops as the fungus is carried over the winter by the resting spores in the soil and it is believed that they retain their vitality for two or three years. The choice of land for the growing of onions is important. The soil should be well drained and wind barriers such as woods, hills and weeds should be eliminated as far as possible, so that there will be a free circulation of air over the field which will dry the plants quickly after rain and heavy dew. When growing onions from sets or planting seed bulbs it is important that these should not be taken from fields where onion blight has been prevalent. Spraying with Bordeaux with a sticker has been recommended by some American authorities. At best it is a difficult task and so far there is no experimental evidence to show that it is profitable here in Ontario. However, in those sections of the Province where onion blight causes serious loss nearly every year, spraying in conjunction with the other methods of control should be given a fair trial. Spray with Bordeaux mixture, 4 pounds bluestone, 8 pounds hydrated lime and 40 gallons of water. To this mixture add 3 pounds of resin fish oil soap as a sticker. The spraying should be started if the weather becomes wet towards the end of June and an application made at least once a week if it is a wet season. In order to avoid destroying the onion plants the sprayer (if a power outfit) should be equipped with a very long boom and many nozzles or with two or more leads of hose so that a man at the end of each hose may spray three or four or more rows at a time.

ONION SMUDGE. This is a disease which is common in Ontario. In wet seasons it seriously disfigures white onions. It does little or no harm to yellow or red onions.

Symptoms. The most pronounced symptom is the dark green or black smudge on the bulb or neck of the onion. Sometimes the surface of the smudge spots is uniformly black. Frequently however, the black smudging is in concentric circles. The smudging may be so extensive as to cover the greater portion of the bulb and disfigure it very badly. In severe cases the fungus grows through the outer scales into the living tissue below, causing collapse of the fleshy scales. The disease may appear at any time in the life of the onion plant in storage or during transportation as well as in the field. Sometimes it causes a damping off of the seedlings. This symptom of the disease has not been observed in Ontario.

Cause. This disease is caused by the fungus *Colletotrichum circizans* (Berk.) Vogl. This fungus passes the winter on onions, on sets and in the soil. It is only under the most favourable conditions of moisture and temperature that it can attack growing onions and cause disease. It is carried long distances on bulbs and sets, and possibly on the seed. Most of the infection takes place in the field. This fungus develops best in relatively high temperatures (75 to 80°F) and requires relatively high soil moisture. It causes most damage when we have hot damp weather shortly before harvest time.

Control. No entirely satisfactory control measures are known. Careful harvesting of the bulbs and thorough drying before placing in storage help to reduce the injury caused by this disease. Practicing a rotation of crops so as to not grow white onions on the same piece of land oftener than once in every three or four years should reduce the loss from this trouble. This disease can be avoided by growing the resistant coloured onions in place of the white or silver-skinned varieties.

BLACK MOULD. This disease frequently follows downy mildew or blight.

Symptoms. The leaves become blackened and covered with a thick brownish-black fungus growth.

Cause. This disease is caused by the fungus *Macrosporium parasiticum* Thumen. This is a weak parasite and seldom if ever appears in abundance on perfectly healthy plants.

Control. No special control measures are required beyond keeping the plants as free as possible from blight and in a healthy growing condition.

PEAS

ROOT ROT AND BLIGHT. In the eastern sections of Ontario, especially in Prince Edward County, this disease has been a serious handicap for many years. Some men have been forced to give up pea growing entirely or to abandon the crop for several years. Frequently a whole field of peas will die down just about flowering time and produce little or no seed.

Dr. R. E. Stone of the Botanical Department has made a special study of this disease and the following account of it is based on his observations and experiments.

Symptoms. The disease generally becomes noticeable just about the time that the peas are coming into bloom, although in severe cases it may be noticed earlier than this. The lower leaves turn white or grey and in a few days or a week the plants wilt down. The roots of such plants are usually brown and rotten. The outer layers or cortex slough off readily and the little feeding roots are all destroyed. On the stem just at the surface of the ground there is generally a blackened area.

Cause. This disease appears to be due to two fungi—a species of *Fusarium* and a species of *Pythium* working on the pea plants. These are soil fungi, that is, they are capable of living in the soil for a considerable period of time.

Control. First, crop rotation; second, the use of resistant varieties.

If this disease has been very serious a rotation of crops should be followed in which peas are not grown on the same soil oftener than once in five years.

Field tests in Ontario have shown that the following varieties of peas are those most resistant to root rot and blight: Green Admiral, Yellow Admiral, Rice's 330 and Horal.

BLIGHT OR LEAF SPOT OF PEAS. This disease is commonly seen in Ontario but seldom causes enough injury to attract attention.

Symptoms. Stems, leaves, pods and seeds are affected. Stems of infected plants show discolored areas of dead tissue, sometimes extending completely around them, destroying the shoot. Diseased leaves show round or oval discolored spots from $\frac{1}{8}$ th to $\frac{1}{2}$ inch in diameter. On the pods sunken spots much like those of bean anthracnose are seen, but pale in colour.

Cause. This disease is caused by the fungus *Mycosphaerella pinodes* (Berk. and Blox.) Stone. This fungus passes the winter chiefly as dormant fungus threads (mycelium) in the seeds.

Control. So far it has not been necessary to practice any particular control measures for this disease in Ontario. If it should become serious non-infected seed should be sown. This can be obtained by selecting it from healthy pods. Spraying with Bordeaux mixture beginning when the plants are from 2 to 4 inches high and repeating at intervals of 5 to 10 days, according to the weather, is also recommended. Such treatment would not be worth while for the general crop but it might be advisable to apply it on a small scale to plants set apart for seed production, since healthy pods bear healthy seeds and healthy seeds will produce a clean crop the following year.

POWDERY MILDEW. This disease is frequently seen in Ontario but seldom causes serious damage.

Symptoms. Leaves, stems and pods become covered with a whitish or greyish mildew. Later minute black fruiting bodies (perithecia) are to be seen scattered over the mildewed surfaces.

Control. This disease is seldom injurious enough to call for any special treatment. Experiments conducted in the United States have shown that it can be controlled by spraying with Bordeaux mixture, 4 pounds copper sulphate, 8 pounds hydrated lime and 40 gallons of water. One or two applications should be given.

BACTERIAL WILT OF FIELD AND GARDEN PEAS

(*Phytophthora pisi*) Sackett, S.A.B.

Though we have occasionally found this disease in pea crops in Ontario, it has not, so far as we are aware, been reported as causing heavy losses in the Province such as it has caused in some parts of the United States.

Symptoms. This disease occurs as canker on the lower part of the stems and as a podspot and leaf spot, and it may also be found as a spot on the seed peas within infected pods.

When the disease gets established in young plants three or four inches high, the upper leaves will have a bruised, watery, yellowish appearance and the lower leaves be dead or dying. The stems of such plants are almost always dark brown or black and considerably shrivelled. Such plants usually die.

In somewhat older plants that are six or eight inches high, where the infection appears to have taken place at a later period, the diseased part of the stem is watery, olive-green to olive-brown in colour. The leaves attached to it first become limp and discoloured in the same way, and later die, turn brown and shrivel up.

The root and that part of the stem below ground do not usually become affected. The stem infection starts in most cases about an inch above the ground line and moves up the stem towards the growing tip. Droplets of a pale yellow exudate are occasionally found on the diseased part. Sometimes below the diseased area on the stem the plant will throw out two or three fresh branches, which under favourable conditions may produce healthy tops, though as a rule they do not make the rank and vigorous growth characteristic of the earlier ones.

If the vines become diseased when they are small and the main vine dies before branching takes place, the chances are that no branches will be formed and the plant will be killed outright.

The leaves may develop the disease independently of any other structure and die before the stems show any trace of the trouble.

On pods the disease first appears as small, water-soaked spots which gradually enlarge, turn yellowish and then brown. If young pods are infected severely they shrivel up and die. Where diseased pods mature, the seed inside may have the disease established in them near the hilum, and the surface of the seed may be coated with the bacterial exudate from the diseased interior surface of the pod.

Cause. The bacteria gain entrance to the plants mostly through wounds but also through the stomates. They feed on the plant juices and spread through the surrounding tissue by means of the intercellular spaces. They do not get established in the vascular system.

Control. The bacteria overwinter in the form of a dry bacterial film on the surface of the seed from diseased pods, and also in the seed coat. They will live under such conditions for at least ten months. When infected seed is sown, a certain percentage of plants coming from it will be infected; and such infected plants are centres for the dissemination of the disease in the field.

Use seed from crops that are known to have been free from the disease.

POTATOES

LATE BLIGHT AND ROT OF POTATOES. This is the most destructive disease of potatoes in the Province. In wet seasons it frequently destroys a large proportion of the crop. The effects of the disease are not noticed usually until late summer—August or September. Frequently however, if the weather is wet about the middle of July the disease may be observed in the fields by the middle or end of the month. It is always worse on low lands and on the heavier types of soils.

Symptoms. This disease as the name implies causes a blighting of the leaves and a rotting of the tubers. The blight is usually seen first on the lower leaves generally at the margins. On the infected leaves irregular dark spots or blotches are observed. These have a water-soaked appearance when held up to the light. On the under surface of these blotches especially around the margin a delicate white fungus growth may frequently be seen. In wet weather the blotches enlarge rapidly and the whole leaf is in-

volved, becomes soft, brown, rotten and droops. In this way all the tops may be destroyed in a few days. If dry weather checks the development of the disease the spots do not enlarge but become dry, brittle and brown. On some of the infected tubers pits or more or less depressed areas are seen. Sometimes these have a somewhat purplish or reddish tinge and a water-soaked appearance. If the diseased potatoes are cut, a rusty brown dry rot is seen in the flesh just beneath the skin. Infected tubers dry rot in the field or in storage. Tubers when dug may show no signs of rot but if they have been produced by blighted plants, the rot is very likely to develop in about three weeks after they are placed in storage. A wet soft rot often develops in wet seasons. This is frequently seen when the potatoes are dug and is due to secondary organisms which gain entrance to the tubers through the dead areas produced by the fungus which causes the Late Blight and Rot.

Cause. Late Blight and Rot is caused by the fungus *Phytophthora infestans* (Mont.) De Bary. This fungus is rapidly spread through the crop during wet weather by means of numerous spores produced on the lower surface of the affected leaves and scattered by rain, wind and insects. Some of these spores are washed off the leaves down through the soil on to the tubers which they are able to infect. Tubers are also often infected by coming in contact with blighted tops and contaminated surface soil when they are being dug. The fungus is carried over the winter chiefly as

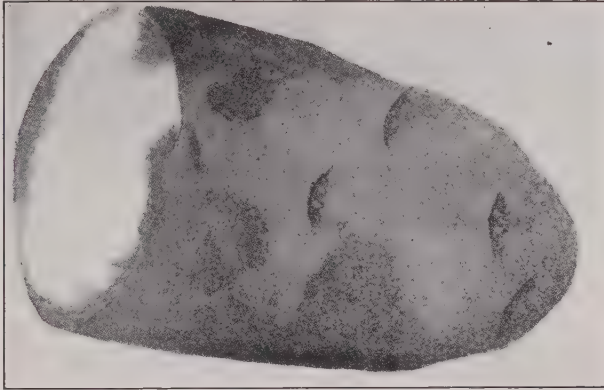


Late Blight.



Early Blight.

fungus threads (mycelium) within infected tubers. Slightly infected tubers show little or no external evidence of the disease. When infected tubers are used for seed the fungus threads may develop in them and produce spores on the surface of the seed pieces or the fungus threads may grow up into the sprouts and produce spores on the outer surface of the growing shoots. The spores produced on the seed pieces or on the developing shoots may be washed or splashed by rain to the leaves which they are able to infect. These infected leaves soon develop blight. There is also some evidence to indicate that the fungus may be carried over as resting spores in the diseased tops. This however, has not been demonstrated in Ontario. The conditions which favor the development of this fungus are excessive moisture, cool nights and warm days.



Characteristic Rot due to the Late Blight and Rot Fungus.
(After Gussow.)

Control. Spraying with Bordeaux mixture is the most reliable means of preventing Late Blight and Rot. Commence spraying when the potato beetle eggs are just hatching, which will usually be when the potato plants are from five to eight inches high, and keep the foliage covered with Bordeaux throughout the season taking special precautions to see that it is well covered during wet weather. Do not put off spraying because it looks like rain for once dry the spray mixture will remain on the leaves and be on at the critical time. This statement will be understood when it is realized that infection takes place during or immediately after rain. For the first application use Bordeaux mixture (formula 4 pounds copper sulphate, 6-8 pounds hydrated lime and 40 gallons of water). Add 2 pounds of arsenate of lime (calcium arsenate) to each 40 gallons. Repeat the spraying often enough to keep the foliage well covered. Add the arsenate of lime to the Bordeaux only when required for potato beetles. No stated number of sprayings with the Bordeaux can be recommended; the number depends on the weather—the wetter the weather the larger the number. If the season is favorable for Blight and Rot continue the spraying until the plants have finished their growth and died or have been destroyed by frost. It is very important to use plenty of Bordeaux at each application. Forty gallons may be sufficient to cover an acre of potatoes when the plants are small but when the plants are large from eighty to one hundred gallons or more may be required for each acre. The best results are obtained by apply-

ing the Bordeaux under high pressure in the form of a fine mist so as to cover both surfaces of the leaves. High pressure power sprayers which deliver plenty of the Bordeaux to thoroughly cover the vines are the most satisfactory machines for spraying.

Dusting is sometimes practised instead of spraying. Copper-lime dust is used. On the whole the results from dusting have not been as satisfactory as those from spraying. Some growers, however, prefer dusting to spraying because it requires less time. The best results from dusting are obtained from frequent and heavy applications of the copper-lime dust.

Other means which can be used to lessen loss from this disease. Plant the more rot resistant varieties of potatoes (See O.A.C. bulletin 239). Avoid soils that are not thoroughly underdrained either naturally or artificially. Plant certified seed potatoes. These are potatoes known to be comparatively free from disease. When the vines are blighted allow them to die and become thoroughly dry before digging the potatoes. Remove the potatoes from the field as soon after digging as possible. Sort them carefully and store in a cool, dry cellar, spreading out as thinly as possible. The proper temperature for storage is about 38°F.

EARLY BLIGHT. This disease is common and in some years causes noticeable damage. It sometimes appears when the plants are small but it is most abundant about the time the potatoes are in blossom. In severe cases the foliage is badly damaged and the tubers remain small. Unhealthy plants and those attacked by the flea beetle suffer most from this disease.

Symptoms. Small scattered greyish-brown circular spots are first observed on the leaves. These take on a minutely velvety appearance and gradually become larger and sometimes run into each other until in some cases half the leaf may become brown and curled. As the spots enlarge faint concentric rings appear on them described as "target brand" markings. Leaves which are very badly spotted turn sickly yellow in colour.

Cause. The causal fungus is *Macrosporium solani* E. & M. This fungus is carried over the winter by means of spores in the soil and by fungus threads in diseased potato tops and weeds.

Control. Spray with Bordeaux mixture as directed for Late Blight and Rot. Take special care to see that the early applications are very thoroughly applied. A three to five year rotation of crops will also help control this disease. Weeds closely related to the potato such as Nightshade and Ground Cherry should be destroyed as they harbour the causal fungus.

COMMON SCAB. This scab is familiar to nearly every potato grower. It is however, not confined to the potato but is sometimes seen on garden beets, sugar beets, turnips and radishes.

Symptoms. It is easily recognized by the roughened corky spots on the skin of the tubers. These may be few and scattered or numerous and close together so as to disfigure badly the potatoes. Sometimes there are also blackened pocket-like cavities. Scab does not injure the flesh of the tubers to any great extent but it renders them unsightly and hence not readily saleable when potatoes are plentiful.

Cause. Common scab is caused by one of the higher bacteria known as *Actinomyces scabies* (Thax.) Gussow. This organism is carried over the winter on seed potatoes and in the soil. It remains in the soil for several years after a crop of scabby potatoes has been produced. It will also pass through the intestines of stock fed on scabby potatoes. This organism appears to be native to some soils. A few scabby potatoes in a bag may contaminate the whole lot. It thrives best in an alkali soil and is checked by acidity. It develops most readily in a soil rich in organic matter and at a comparatively high temperature.

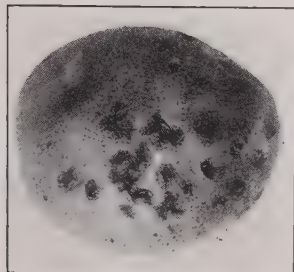
Control. When a field is thoroughly infested with the scab organism it is very difficult to grow a clean crop on it. There are however, certain recommendations which if put into effect will reduce very markedly the amount of scab. Follow a rotation of crops. If scab is very bad it is not advisable to plant potatoes on the same land oftener than once in five years. Plant potatoes after clover sod if possible. Heavy applications of barnyard manure should not be made direct to the potato crop but if necessary given at some other point in the rotation. Avoid alkali fertilizers such as lime and wood ashes. If commercial fertilizers are used they should be of an acid nature. Sulphur and inoculated sulphur have been recommended by some authorities for the prevention of scab. The results obtained in experiments here at the College with sulphur and inoculated sulphur are not such as to warrant the recommendation of either of them for the prevention of scab. Treating the seed potatoes with formalin or corrosive sublimate helps to lessen the amount of scab. The effectiveness of seed treatment varies with different soils. On some soils it is very effective while on other soils the results are far from satisfactory, probably due to the fact that the soil is heavily infested with the scab parasite and in such a condition as to favour its development.

Directions for treating seed potatoes with formalin to prevent common scab.

Select tubers free from all signs of rot and bruises and as free as possible from scab, and disinfect them before they are cut by soaking them for two hours in a solution made by adding one pint of commercial formalin to thirty gallons of water. The same formalin solution can be used to treat



Powdery Scab (after Morse).



Common Scab. (Original.)

successive lots of potatoes. Thirty gallons is sufficient to treat from forty to fifty bushels if ordinary precautions are taken not to waste the solution when dipping. Wash all crates, bags etc. which are used in handling the potatoes with the formalin solution. After the potatoes are removed from the solution they should be spread out on clean grass or clean bags to dry. If the potatoes are not all disinfected on the same day it is advisable to make up a fresh supply of formalin for each days treatment. (See note on formalin, page 60).

Directions for treating seed potatoes with corrosive sublimate to prevent common scab. (See page 39).

POWDERY SCAB. This disease was first reported as occurring in Canada about 1912. It was found in Prince Edward Island, Nova Scotia, New Brunswick, Quebec and Alberta. In 1914 it was reported from Northern Ontario. It does not seem to be established in the southern parts of the Province. It does not appear to cause serious trouble in warm, comparatively dry soils.

Symptoms. Tubers infected by the Powdery Scab fungus become covered with conspicuous scab spots which are more clearly defined, more elevated and smoother on the surface than Common Potato Scab. When the skin of the scab spot is broken the cavity beneath is seen to be filled with a brownish or greenish powder. The chief injury is the unsightly appearance of the tubers. In very severe cases however, the potatoes may be stunted and malformed and there is always a greater tendency for infected tubers to shrivel and dry rot in storage.

Cause. The cause of Powdery Scab is a slime mould known as *Spongospora subterranea* (Wallroth) Johnson. This fungus is spread mainly on seed potatoes. It is introduced into new localities chiefly through planting "seed" which is infected or which has come in contact with infected tubers or with bags, crates, implements, etc. which have been used in handling them. Once the fungus gains entrance to a soil it will apparently remain there for a number of years. It develops best in wet cool soils and it will not develop in warm, comparatively dry soils.

Control. Secure seed potatoes from a district known to be free from Powdery Scab. Plant only sound tubers free from scab and as a precaution disinfect them with either corrosive sublimate or formalin. (See directions under Common Scab, page 39). Good drainage and a long rotation of crops will also aid in the control of this disease.

RHIZOCTONIA OR BLACK SCURF. This disease is very frequently met with in Ontario and in seasons of excessive rainfall often results in a noticeable reduction of the crop. It does more damage in Northern Ontario than it does in the southern parts of the Province.

Symptoms. Tubers are very frequently seen with what appear to be lumps of hardened soil adhering to them. These are black in colour when wet. They vary in size from mere specks to one-quarter of an inch in diameter. Sometimes they are very numerous and quite noticeable. They are known as sclerotia and consist of compact masses of resting fungus threads (mycelium). The skin of the potato beneath them is often roughened and russeted but the flesh of the tuber is not injured to any appreciable extent. If potatoes however, with these sclerotia adhering to them are planted

the fungus may spread into the developing sprouts and kill them before they get above the ground. This is one cause of "misses" in the rows. Later in the season several other symptoms may develop. Young shoots may wither and die and if they are pulled up and examined there will be found near the base of the stems brown dead areas often encircling them. Sometimes large plants become sickly yellow and develop many fine spindly shoots. Such plants also show dead brown areas near the base of the stems and on the underground parts. Occasionally at the base of the stems of affected plants clusters of small tubers may be found and quite frequently small greenish potatoes are seen on the stem above the ground. Such aerial tubers are very characteristic of the disease but they may result from other causes such as injury to the stem by cultivation.

Cause. This disease is caused by the fungus *Corticium vagum* B. and C. This fungus attacks many plants besides the potato. Among the more important hosts of this fungus are carrots, beets, beans, cabbage, parsnips, onions, turnips, peas, celery, rhubarb, spinach and lettuce. The fungus lives over winter in the soil and on the tubers in the form of fungus threads (mycelium) and sclerotia. It is probable that few soils are free from it.

Control. Dig the potatoes as soon after they are mature as possible. The longer they are in the soil, especially in a wet fall, the greater the chance of sclerotia developing on them. Treat the seed potatoes with corrosive sublimate before they are cut for planting. This seed treatment should be done when the potatoes are dormant, that is, before the buds in the eyes begin to grow.

Directions for treating seed potatoes with corrosive sublimate to prevent rhizoctonia and scab.

Select tubers free from all signs of rot and as free as possible from scab and little hard lumps on the surface. Place them in a pile on the barn floor, sprinkle them thoroughly with water, and cover them with sacks and leaves for twenty-four hours. At the end of this time soak them for an



Hard black lumps (sclerotia) of *Rhizoctonia* on Potato.
(Original.)

hour and a half in a solution of corrosive sublimate of the strength of 4 ounces of corrosive sublimate to 25 gallons of water. In preparing the solution dissolve the corrosive sublimate in a little hot water and then add it to 25 gallons of cold water. Fill a barrel or trough with the potatoes, then add the solution until the potatoes are covered. Leave for the required time, then drain off the solution into another receptacle. After each lot of tubers has been treated add one-half ounce of corrosive sublimate and keep the volume of the solution constant by adding more water when necessary. After four lots of tubers have been treated the solution should be entirely renewed. After this treatment the usual precautions should be taken to prevent the tubers becoming re-infected.

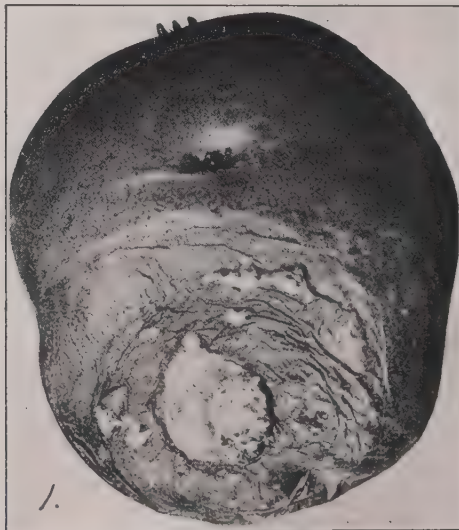
N.B.—Corrosive sublimate is a deadly poison and should be kept out of the way of children and stock. Potatoes disinfected with it should never be used for food for man or beast. (See note on corrosive sublimate, page 60).

FUSARIUM DRY ROT. This rot frequently develops in potatoes in storage late in the winter or early spring.

Symptoms. A firm, cheesy, dry rot develops in the tubers. This is often confined more or less to one end of the potato. The surface of the rotten portion is often covered with a white or pinkish fungus growth. Sometimes the whole potato shrivels and dries to a hard mass.

Cause. Various species of *Fusarium* are the chief cause of this trouble. Some of these gain entrance to the tuber if the skin is broken when the potatoes are being harvested, transported or stored.

Control. Handle the potatoes in such a way to eliminate bruising as much as possible.



Fusarium Dry Rot of Potatoes. (Original.)

POTATO CANKER OR WART DISEASE OF POTATOES. This disease was found in Canada in 1912, but is not found in this country at the present time. This is owing to the fact that at its first appearance very prompt measures were taken to stamp it out, and probably to some extent to the fact that the two commercial varieties of potatoes which are so extensively grown in Ontario, namely Green Mountain and Irish Cobbler, are immune to this disease. It is a very serious disease to susceptible varieties of potatoes and it is important therefore that Ontario growers should be able to recognize it in order that they may report its presence promptly should it at any time appear in their crop.

Symptoms. Potato Canker is not usually observed until harvest time. Badly affected tubers are simply brownish-black masses of warty excrescences not in the least resembling potatoes. Tubers showing the early stages of the disease have some of the eyes slightly protruding and composed of simple or compound groups of small brown nodules. In the early stages this disease is very likely to be overlooked by the casual observer.

Cause. This disease is caused by the fungus *Synchytrium endobioticum* (Schilb.) Perc. This organism is carried over from season to season in the soil or in tubers. It may be carried into clean soil by drainage from infested soil, by farm implements and on the feet of men and animals.



Potato Canker. (After Gussow.)



Leaf Roll. (Photo by R. E. Stone.)

Planting infected tubers or tubers which have come in contact with diseased tubers is another way that this organism is spread. It is also spread in manure from animals to which diseased potatoes have been fed and by garbage into which warts or peelings from diseased tubers have been thrown.

Control. Grow varieties of potatoes known to be immune to Potato Canker. In tests conducted in the United States the following varieties have been found to be immune: Green Mountain, Irish Cobbler, Early Petoskey, Peach Blow, McCormack and Burbank. Among those valuable varieties which were found to be very susceptible to Potato Canker are: Rural New Yorker, Early Rose and American Giant. If susceptible varieties of potatoes are grown be on the watch for this disease and if suspected potatoes are found send samples to the Dominion Botanist, Central Experimental Farm, Ottawa, or to the Botanical Department, Ontario Agricultural College, Guelph.

LEAF ROLL. In the past this disease has been very prevalent in the potato growing districts of Old Ontario. Since the use of certified seed potatoes has become general very much less leaf roll is seen in the Province. This disease may reduce the yield to a very marked extent.

Symptoms. These are very variable. Affected plants are always more or less dwarfed and in some varieties the leaves assume a characteristic upright, almost staring habit instead of drooping over in the normal way. This symptom is sometimes absent, the plants presenting instead a low-headed bushy appearance. When the crop is badly affected the poor growth of the foliage is very noticeable. It is practically never as green on affected plants as on healthy ones and occasionally on certain varieties it takes on a purplish or reddish colour at the tips and around the margins of the leaves. Rolling of the lower leaves is always associated with the disease. It is often rather inconspicuous and may not extend beyond the leaves lying close to the ground although it may affect the intermediate and even the topmost leaves. Marked rolling of the upper leaves however, is often seen on plants not affected with Leaf Roll. The rolled leaves of plants affected with this disease begin to die early. The harsh leathery texture of such leaves is a constant symptom. This point may be tested by feeling them with the fingers. The tubers of affected plants are small and are borne generally on very short tuber branches (stolons) or even attached in a cluster to the stem.

Cause. This is one of the virus diseases. The virus can be transmitted by transferring the sap from affected to healthy plants. Aphids or plant lice have been shown to be the chief carriers of the virus although it is probable that they are not the only carriers. The disease does not live over winter in the soil unless tubers that might produce volunteer plants are left in the field at digging time. Leaf Roll is transmitted chiefly through the "seed." Tubers from affected plants almost always produce diseased plants.

Control. The most important means of control is the use of healthy "seed." The man who is growing potatoes for table stock can avoid serious loss from Leaf Roll by purchasing from time to time certified seed potatoes. Certified seed potatoes should be planted at some distance from other potatoes in order to prevent leaf roll being carried to them.



Black Leg of Potato. (Original.)

and not so noticeable in others. The stalks of diseased plants are often more bare near the ground than those of healthy ones, partly because the affected foliage does not spread out and droop down normally and partly because the lower leaves sometimes fall off in the last stages of severe attacks. The symptoms of Mosaic are best detected on a cloudy day or when the plants are in the shade. Sometimes the plants are much stunted and have very strongly wrinkled or rugose leaves. This form of the disease is very conspicuous and is often called Curly Dwarf. Although the yield may be reduced the individual tubers from a diseased plant may be as large and appear as perfect as those from a normal one.

Cause. This is another virus disease. Aphids or plant lice are known to be the carriers of the virus from diseased to healthy plants. The pink and green aphid, one of those which is often found on potatoes, has for its winter host the wild and cultivated roses. In the spring the aphid leaves the roses and goes to potatoes and many other plants. It is very likely that the leaf hopper and other insects may also act as carriers of the virus. It is known that the virus may be transmitted by bruising diseased leaves and then rubbing the sap into healthy leaves or in any way by which sap is transferred. Like Leaf Roll, Mosaic is transmitted through the "seed" and is spread very largely by the use of "seed" from diseased plants.

Control. The control measures for Mosaic are the same as for Leaf Roll (See page 42).

BLACKLEG AND BACTERIAL SOFT ROT OF POTATOES

(*Erwinia atroseptica*) van Hall, S.A.B.

This disease is of fairly common occurrence and in wet seasons is apt to cause considerable loss in the potato crop.

Symptoms. Foliage and Stems. The tops of such potato plants as are affected with blackleg lose their bright green colour, which fades away to a brownish or dirty yellowish green, and present a general drooping or wilted appearance. The leaves have their edges turned upward or inward, and are limp and flaccid to the touch, contrasting in this last particular with plants suffering from "leaf roll", in which case the curled leaves are harsh and brittle to the touch.

The lower part of the stems of such plants show a dark brown or black discolouration, hence the name blackleg. This discolouration is more often found below the soil surface from the seed tuber up, but may extend upwards for an inch or two above the soil. In many cases such discoloured tissue will be rotting with a soft, slimy rot, soon followed by a shrinkage of the affected area, after which the top falls over on to the soil and rots away. An examination of the seed tuber from which the plant has grown will usually show it to have rotted away with a soft, slimy, wet rot, often nothing but the skin being left. The soil underneath such a rotted seed tuber frequently appears as though it had been wet puddled, owing to rapid extraction of water from the seed tuber during the rotting process.

The disease usually develops in the young plant from an infected seed tuber. In some cases sprouts from such a tuber will scarcely reach the surface of the ground before they die from the rot. In other cases sprouts will reach the surface, develop roots and produce a top before signs of the disease are visible. Sometimes one or more stems of a plant will be affected with the disease and die off, while other stems of the same plant may reach



Potato Tubers, showing Bacterial Soft Rot in various stages of development, some tubers entirely rotted, others only partially affected. (Original).

1. Six tubers that contracted the disease directly through the stem from the parent plant.
2. Six tubers that contracted the disease at the eye end from coming in contact with other diseased tubers.

maturity and produce tubers. In such cases there is a strong probability of the tubers becoming infected with the characteristic soft wet rot. Particularly is this the case in wet seasons. In such cases the disease passes from the infected parts underground along the tuber stems and thus gains entrance to the tubers. Other tubers in close contact with the diseased ones may get the disease from such close contact.

Tubers. In tubers where the disease is not far advanced the tuber may at first sight appear sound, but on closer examination, particularly if the specimen be washed with clear water, the skin over a diseased area will appear slightly discoloured, indicating a water-soaked condition of the tissue beneath. The discolouration will be more noticeable around the edge of the diseased portion, showing up as a reddish brown line. If pressure with thumb or finger be applied to such a discoloured area the skin slips or peels off fairly readily and the tissue immediately beneath is found to be soft rotted, sometimes only to a very slight depth, at other times to a much greater depth, depending on the extent to which the disease has developed. When the rot is far advanced in the tuber the great bulk of the tissue will be soft and mushy. On breaking the skin the pulpy interior oozes out, often showing gas bubbles and giving off an offensive odour. On exposure to the air the soft pulp darkens in colour. Sometimes the interior of a diseased tuber is completely rotted to a soft pulp, but the skin, being intact, keeps its rotundity and smoothness as a result of the gas inside the pulp. Slight pressure of such a tuber causes it to collapse.

Cause. The bacteria which cause this disease gain entrance to the growing plant at the bottom of the stem from diseased seed tubers. As they grow and multiply they produce an enzyme (digestive substance) which dissolves the middle lamellae (cement material) which binds the cells together in healthy tissue. As the solution of this binding substance takes place the tissue breaks down into the characteristic soft, wet rot.

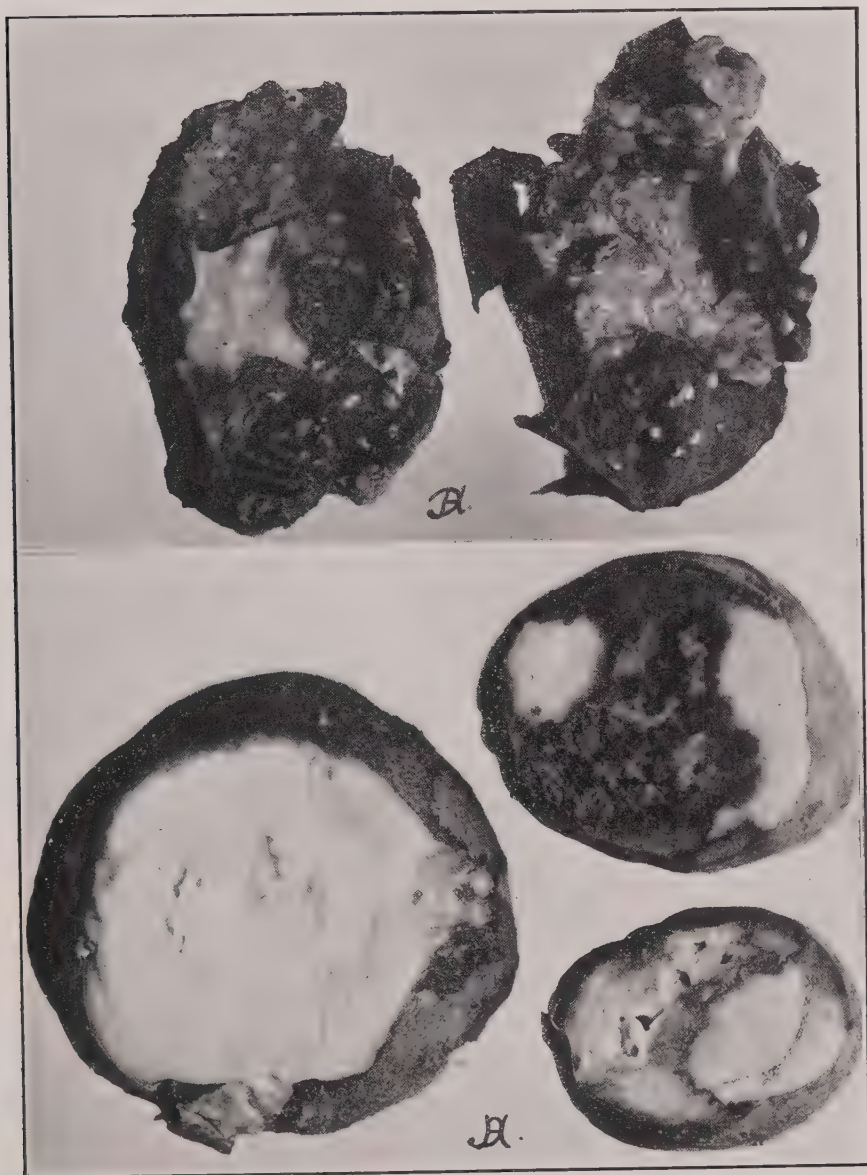
Control. (1) Do not plant seed tubers that show any signs of disease. It has been shown by one investigator that the seed corn maggot (*Phorbia fusiceps*) will inoculate healthy seed tubers after they have been planted, with the bacteria that cause the disease. His theory is that the adult flies of this maggot will feed on diseased potatoes and so get contaminated with the bacteria. They lay their eggs in cracks of the soil near planted seed tubers. The surface of the eggs are contaminated with the bacteria at the time they are deposited. When the eggs are hatched the maggots get contaminated from the eggs, and thus, when they feed on the seed potatoes, inoculation of the same takes place.

(2) Growing plants that show signs of blackleg should be carefully removed from the crop and burned.

(3) In harvesting potatoes from a crop in which the disease has occurred, care should be taken to discard all tubers that show signs of rot. Unfortunately, only those tubers in which the disease is fairly well advanced are readily noticed as being diseased. A considerable proportion may have the disease so lightly established as not to be noticed without very careful observation. If such tubers are stored in bulk in a pit, or in bags in a cellar, the rot is sure to spread. If such tubers are allowed to dry out, the rot may be checked in many cases. It is in such tubers that the disease is carried over for next season. Consequently tubers that have been obtained from a crop in which blackleg has been present should never be used for seed purposes. They should be sold for immediate consumption.

(4) Dipping seed potatoes in corrosive sublimate 1-1000, at time of cutting, aids in preventing the disease.

(5) Land on which potatoes are grown should be well drained.



Tubers in advanced stages of the Bacterial Soft Rot, taken directly from the field.
(Original).

MOSAIC. This disease has been observed in many fields in Ontario. When it is severe there is a very noticeable reduction in the crop.

Symptoms. The foliage of plants affected with Mosaic is somewhat wrinkled or corrugated and mottled with faint, light green or yellowish spots. These symptoms vary considerably, being well marked in some cases

TIP-BURN OR HOPPER-BURN OF POTATOES. This trouble is very frequently seen in abundance in Ontario in hot dry summers. When serious it causes a marked reduction in the yield.

Symptoms. There is at first a slight wilting and rolling inwards of the edges of the leaves which soon turn brown. When the trouble is serious this browning and curling may extend to the midrib or near it over a considerable portion of the leaves.

Cause. There are two types of injury, (1) true tip-burn which is the result of hot sunshine and warm dry winds causing an excessive loss of water from the leaf tissue. (2) hopper-burn caused by apple leaf hoppers (*Empoasca mali*) puncturing the leaf veins and sucking the juice. This insect may often be seen rising in swarms as one walks through an infested field.

Control. Keep the soil rich in humus and see that the potatoes are repeatedly and thoroughly cultivated to conserve moisture. Spray with Bordeaux mixture as for Late Blight and Rot. Spraying has a direct effect on the true tip-burn as well as acting as a repellent for leaf hoppers.

TOMATOES

BLIGHT OR LEAF SPOT OF TOMATO. This is the commonest disease of tomatoes grown in the open in Ontario. In certain sections of the Province it causes serious loss to tomato growers by destroying the foliage early in the season, with the result that the fruit does not ripen properly or is unscaled. It causes most damage in seasons of high temperature and high humidity.

Symptoms. Blight or Leaf Spot is easily recognized by the small, grayish-brown angular spots containing minute black specks which appear on the leaves and stems. Badly spotted leaves wither and dry up. The lower leaves are first affected and the disease spreads upwards, often completely destroying all the foliage of the plants except the new growth near the tips. Sometimes small spots occur on the fruit also.

Cause. The fungus which causes this disease is *Septoria lycopersici* Speg. This fungus produces countless spores in little black fruiting bodies (pycnidia) in the diseased spots on the leaves. During periods of high temperature and excessive humidity these spores are liberated and carried to neighbouring leaves or plants by insects, wind, rain and the hands and clothing of pickers. This fungus is carried over the winter in the diseased leaves and stems which drop to the ground, and in the remains of certain weeds which are also attacked by it.

Control. This disease frequently starts in the seed bed. In order to prevent this the following precautions should be taken. Any wood around the seed bed should be drenched with a solution of formalin (1 pint to 20 gallons of water). If Leaf Spot has been prevalent in former years the soil in the seed bed should be renewed or sterilized with steam or formalin. The plants in the seed bed should be sprayed at least twice with Bordeaux of the strength of 3 pounds of copper sulphate, 6 pounds of hydrated lime and 40 gallons of water, to which has been added resin fish oil soap as a sticker. The first spraying should be given when the plants are three or four weeks old and the second about a week before they are set out in the field.

The two sprayings given before the plants are set out in the field should be all that are necessary to control the disease in early tomatoes. Late tomatoes should receive two more sprayings after they are set out in the field with Bordeaux and resin fish oil soap. The first should be given three or four days after the plants are set and the second in ten days or two weeks time. Ordinary Bordeaux does not adhere very well to the surface of tomato foliage and it has been found necessary to add resin fish oil soap as a sticker in order to secure the best results from spraying. (See directions concerning resin fish oil soap, page 60).



Leaf Spot of Tomato. (Attacked leaves and stem).
(From Ohio Bulletin 73).

If Leaf Spot is very troublesome a rotation of crops should be followed so that tomatoes are not grown upon the same piece of ground oftener than once in three or four years. When such a rotation of crops is followed it is much easier to keep Leaf Spot under control.

BLACK ROT, RIPE ROT, TARGET SPOT. This is a very common disease of tomatoes in Ontario. In wet seasons it causes very serious losses to the growers of canning tomatoes in Eastern Ontario.

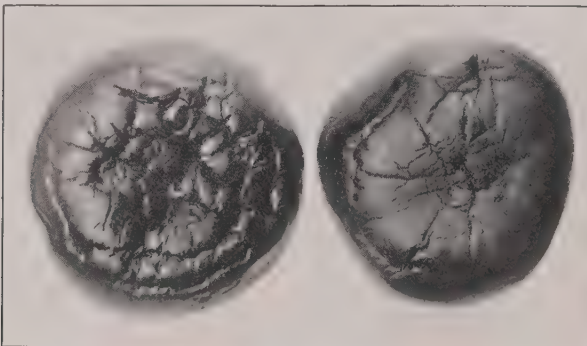
Symptoms. On the fruits are seen dark brown or black sunken rotten spots. Some of these may be an inch in diameter. The discolorations from the rot usually extend to the centre of the fruit rendering it unfit for canning purposes. On the leaves may be observed somewhat circular, dark brown spots which are sometimes one-half an inch in diameter. They are readily recognized by the peculiar ring-like or target-like markings, hence the name "Target Spot". The spotting of the leaves is of comparatively little importance. It is the rot on the fruit that causes the loss.

Cause. The fungus *Macrosporium solani* E. & M. which causes Early Blight of potatoes is also responsible for this disease. The life history of this fungus is described under the cause of Early Blight of potatoes (page 36).

Control. The directions given for the control of Leaf Spot of tomato apply also to the control of this disease.

BLOSSOM END ROT OF TOMATOES. This trouble is very common in Ontario both in tomatoes grown outdoors and under glass. It is most abundant outside in seasons when periods of hot dry weather alternate with those of heavy rainfalls.

Symptoms. The trouble appears usually when the first fruits are about half grown or a little later. Slightly sunken water-soaked areas are seen near the tip of the fruit. These are at first lead colored or brownish but soon become lead-brown or black in color and of a leathery texture. Various fungi and bacteria may gain entrance through these injured spots and cause rot which may destroy the whole fruit.



Blossom End or Point Rot of Tomatoes. (Original).

Cause. It has been shown that this disease is not due to any organism. It is one of the so-called physiological diseases due to some condition within the plant itself probably induced by its environment. Improper fertilizers and irregularities in the water supply appear to be important factors in causing this trouble.

Control. Excessive amounts of organic fertilizers such as farmyard manure appear to have a marked effect in increasing this trouble. Avoid over-watering the plants especially in the early stages of their development. The water supply of tomatoes grown under glass should be even and regular. Some growers claim to reduce the amount of this trouble by mulching diseased plants. Others consider that repeated good cultivation to conserve the moisture supply is the most effective preventive measure.

TOMATO MOSAIC. This disease is frequently seen in Ontario both in the field and under glass. It is not an uncommon thing to see fifty per cent. or more of the plants in a greenhouse affected by Mosaic.

Symptoms. The leaves of affected plants may be mottled with light green or yellow or they may be dwarfed and have a peculiar fern-like appearance. Sometimes the leaf segments are so narrow and slender as to appear almost thread-like. This form of the disease is referred to as Shoe-string Mosaic.

Cause. This is a virus disease, that is, the juice of diseased plants contains something which when transferred to healthy plants causes them to be diseased. It is known to be transmitted from plant to plant by plant lice or sucking insects, and by workmen pruning and tying plants in the greenhouse or field. The virus which causes Mosaic lives over the winter in old tomato plants in the greenhouse and in the roots of perennial weeds which are closely related to the tomato such as Ground Cherry (*Physalis* spp.) The same virus also causes Mosaic of tobacco, pepper and petunia and potatoe.

Control. It is not advisable to use tomato plants from a seed bed in which Mosaic has developed. All weeds belonging to the potato family such as Ground Cherry, Horse-nettle and Black Nightshade growing in the neighbourhood of the greenhouse or tomato field should be destroyed. So far as is possible control aphids by spraying or fumigation. In working among tomatoes the hands should be washed repeatedly with soap if there is any possibility that diseased plants are being handled. If potatoes, petunias, egg-plants, peppers and other susceptible crops are grown near the tomatoes, Mosaic may spread from these to the tomatoes.

STREAK OR WINTER BLIGHT OF TOMATOES. This is one of the most troublesome diseases of greenhouse tomatoes in Ontario. It sometimes appears also in field tomatoes but seldom causes severe injury.

Symptoms. The first indications of Streak are a curling and twisting of the upper leaves and younger portions of the stems. Brown sunken streaks appear in the young vigorous growing stems and these increase in width until the whole upper part of the stem may become brown. At first the browning appears to be on the surface only but soon becomes deeper seated and in bad cases involves the woody ring. At the same time these streaks appear on the stem, brown angular spots appear on the leaves between the veins and these brown spots may increase in size until the whole

leaf is involved. Fruit sets very sparingly, often none on the first two or three trusses. The fruits that do set are commonly scabby, deformed and of poor flavor and color. Large soft, sappy vigorous growing plants are those most subject to this trouble. Streak is frequently associated with Mosaic.

Cause. The cause of this disease has not been definitely proven. In England it is considered that *Bacillus lathieri*, the organism that causes Streak of sweet peas is also the parasite associated with Streak of tomatoes. Experiments conducted in the United States and in Canada indicate that it is probably a virus disease. The early investigational work conducted at the college here lead to the conclusion that Streak was probably the result of an unbalanced fertilizer. All investigators appear to agree that an over-supply of nitrogenous fertilizers causes the disease to appear in epidemic form. Poor ventilation, irregular watering and fluctuating temperatures are favorable for the production of Streak.

Control. Dr. Stone of the Botanical Department, Ontario Agricultural College, has been carrying on for a number of years investigations concerning the control of Streak, and as a result of these investigations he makes the following recommendations: Avoid the use of too much manure or nitrogen containing fertilizers such as ammonium sulphate and sodium nitrate. Add acid phosphate or boneflower (3 ounces per plant) and potassium sulphate ($\frac{1}{4}$ ounce per plant) either before transplanting or just after the blossoms appear. Avoid over-watering and then allowing the plants to become too dry. Keep the plants growing evenly by keeping the temperature uniform and watering at frequent intervals but not too much at any one time. Do not attempt to force tomato plants that have been checked.

LEAF MOULD. This disease is frequently met with in greenhouse crops of tomatoes and occurs to a lesser degree in the field.

Symptoms. The leaves, especially the lower surface become covered by an olive-brown mouldy or felt-like fungus growth. Affected leaves turn yellow or brown and in severe cases shrivel and die.

Cause. This disease is caused by the fungus *Cladosporium fulvum* Cke. This fungus is carried over from season to season in old diseased leaves in the soil of the greenhouse. It thrives best in a humid atmosphere and is very susceptible to temperature. The spores germinate best at a temperature of from 65° to 75°F. They will not germinate in a relatively dry atmosphere. Cloudy days increase the virulency of this organism.

Control. Proper ventilation of the greenhouse is the best preventive. The disease will not develop if moisture does not condense upon the leaves. This can be prevented by opening the ventilators and providing a little more heat if necessary. The watering of the plants is best done in the morning of dry sunny days. Bordeaux mixture if applied very heavily and under high pressure at five day intervals will hold the disease in check if the first application is made before the disease appears. This is seldom necessary if the greenhouse is well ventilated and the plants properly watered. Some growers recommend fumigating each house with sulphur before the plants are put in. Such fumigation should never be attempted after the plants are set into the beds.

DAMPING OFF

The seedlings of many plants are liable to be affected by this trouble. It occurs mostly in the seed bed where plants are growing in a crowded condition. It is seldom found in the open field. It is also a common disease in greenhouses where relatively high humidity is maintained and where the plants are not exposed to sunshine and free circulation of air.

Symptoms. The stems near the ground are girdled by brown lesions which cause the plants to fall over and ultimately die.

Cause. Rhizoctonia, species of Fusarium and Pythium de Baryanum are among the commonest fungi causing this trouble.

Control. If serious Damping Off has occurred at some previous time the soil should not be used again, or if used it should be sterilized with steam or formalin. (See page 60). Take the following precautions to prevent the accumulation of too much moisture in the surface soil and reduce the relative humidity of the air about the plants; (1) stir the upper layers of the soil frequently; (2) provide good ventilation so that there is free circulation of air about the plants and expose them as much as possible to sunshine; (3) water the plants in the morning rather than in the late afternoon or evening; (4) sprinkle layer of dry sand over the surface of the soil; (5) avoid too thick sowing; (6) avoid over-watering.

BACTERIAL SOFT ROT OF VEGETABLES

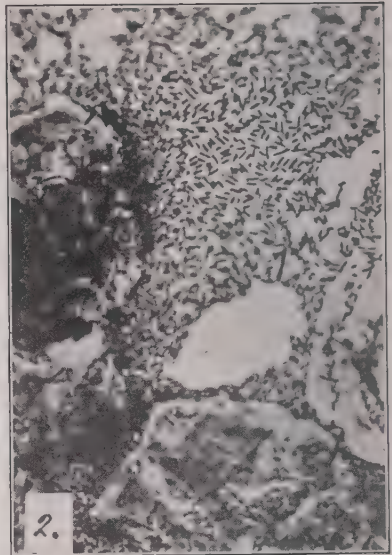
(*Erwinia caratovora*) L. R. Jones, S.A.B.

Bacterial soft rot is a disease liable to attack fleshy vegetables and flowers, particularly carrots, cauliflower, turnips, celery, tomatoes, potatoes, German iris and calla lily, and in a lesser degree, onions, asparagus, salsify, sugar beet, mangel, musk melons and some others. Occasionally the disease results in heavy losses to the grower of these crops.

Symptoms. As the name signifies, the disease results in a soft, wet rot of the plant attacked. The rotted portion of the plant is darker in colour than the rest of the plant. The colour of the diseased part varies from a light, reddish-brown to a very dark brown in the case of white or creamy fleshed plants, such as cauliflower, turnips or heart of celery, and a very dark green, almost black, in case of the green tissues which are attacked. The diseased tissue is very soft and mushy, and frequently has a strong and offensive odour. There is a clear line of demarcation between the diseased and healthy tissues, the disease inducing complete destruction of the tissue as it advances from the point of inoculation.

In cauliflower the disease is found often in the "flower" than in the leaves or stem; the latter parts, however, are also subject to attack.

The disease in the "flower" is very easily noticed, the normal colour of the "flower" being white or creamy and that of the diseased portion light to dark brown, and very soft; and having an offensive odour. The writer has noticed a number of times dark brown areas varying in size, which looked at first sight like soft rotted areas, but which on investigation proved to be discolourations due to excreta of cabbage caterpillars which had been feeding on the leaves overhanging the "flower". In such cases the tissue im-



Bacterial Soft Rot of Cauliflower and Cabbage. (Original.)

1. Bacterial soft rot of cauliflower, natural infection; specimen taken direct from garden.
2. *Erysitella caratovora*, the vegetable soft rot bacillus seen between cells of broken-down, rotting cauliflower. (x 1000 di.)
3. Bacterial soft rot of cabbage. Artificial stab inoculation of a pure culture of *Erysitella caratovora* in healthy cabbage. Photo taken twenty days after inoculation.

mediately below the surface of the discoloured area is not softened as it is in the case of the rot, and the discolouration is only on the surface. Observation has shown, however, in a number of such cases, that the rot has later developed within such discoloured area, thus indicating that in all probability the caterpillar had previously been feeding on a rotted plant and all the bacilli in the portion consumed had not been killed in the process of digestion, but had passed through the alimentary tract of the caterpillar with the excreta; or that the mouth parts and feet of the caterpillar had been contaminated from a diseased plant, and on crawling over the surface of the healthy plant had inoculated it.

In the stem the disease results in a complete softening of the interior, the softened tissue becoming a dirty grey in colour with strong odour. The disease may enter the stem from injury to the exterior caused by the breaking of leaves, or the biting of insects, slugs and caterpillars during cultivation, etc., and from the stem pass up into the "flower", or the stem may become so far rotted that the head will fall off. The stem may also become infected through the "flower".

In the leaves the disease is more often found in the petiole or midrib rather than the blade. It appears as a dirty grey, softened area, which, when in the petiole, soon results in collapse of the leaf.

In *Turnip* the disease most frequently enters at or near the crown, through caterpillar or slug attack, or through injuries received during hoeing or cultivation. It softens or rots the leaf petioles at their base, causing them to fall over; and spreads slowly in dry weather, rapidly in wet weather, through the tissue of the root, inducing a brown coloured soft rot with strong odour.

In *Carrot* the disease enters and develops in much the same way as described for the turnip. It is more apt to spread rapidly through a crop that is thickly sown and not well thinned out, the shade produced by the heavy tops making ideal conditions by keeping the ground moist for the development of the disease when once it gains entrance, and harbouring slugs and caterpillars that spread the disease. Carrots which crack beneath the ground are liable to be attacked by the disease, the soft rot bacillus gaining entrance to the tissue through the cracked surface.

In *Celery* the disease is most often found starting at or near the tops of the young growth. The affected parts become dark brown and very soft and mushy. The parts so affected cease growing, the growing tips being destroyed, and the disease passes down the stem, completely rotting the tissue as it progresses. If the disease starts below the end of the stem, the upper part soon topples over as a result of the softening of the part attacked. The disease spreads from plant to plant through the agency of slugs, caterpillars and insects, particularly the tarnished plant bug, and during the process of handling when cultivating and banking up. When the plants are stored away for winter use, if a plant having the disease is stored with the healthy plants the rot is liable to spread to the healthy specimens.

In *Tomatoes* the disease is very common during wet seasons. It is found most frequently in the fruits that are in contact with the soil after they have commenced to ripen. The bacillus will not readily penetrate through the unbroken skin of the tomato. But when a tomato is resting on the damp earth, that part of the skin in contact with the soil is frequently weakened, thus providing a means of access to the bacillus. This, however, is not the only means whereby the disease enters the fruit. Slugs are very partial to tomatoes just ripening. In their attack on the fruit



Bacterial Soft Rot of Turnip. (Original.)

1. Turnips direct from field badly affected with bacterial soft rot. Shaded areas were soft, pulpy and strong smelling. Evidently inoculated near the crown, probably through wounds made by slugs or caterpillars or during cultivation.
2. Soft-rotting turnips direct from field, in which the disease had been prevalent the previous year. These had evidently been inoculated from the soil through wounds made while hoeing or cultivating.

they eat through the skin, leaving the interior flesh exposed. This exposed surface is an ideal medium for the bacillus of soft rot to develop in. The writer has found many tomatoes, particularly in wet seasons when slugs are plentiful, that have contracted the disease in this way.

Cause. When the soft rot bacillus gets onto a freshly made wound, either small or large, in plants liable to the disease, it feeds on the plant juice which emerges on to the wounded surface, and on this it grows and rapidly multiplies. As it multiplies it produces pectinase, a cytolytic enzyme which dissolves the middle lamellae, the thin strip of tissue which lies between adjacent plant cells. The lamellae are quickly dissolved and form good food for the multiplying bacilli, which, as they multiply, pass along between the cells, filling the intercellular spaces and separating the cells from one another. The protoplasm within the plant cells is plasmolised, that is, it is made to shrink from contact with the cell walls and to contract into an irregular mass within the cell, by the action of the enzymes produced by the bacilli in the intercellular spaces. In this way the collapse of the tissue is brought about, and such tissue constitutes the rotted part of the plant.

Control. Spraying with fungicides, which is so effective in controlling the fungus diseases of plants, is of no avail with bacterial soft rot, as the bacteria which cause the disease act in the interior tissue rather than on the surface; hence the spray will not reach them.

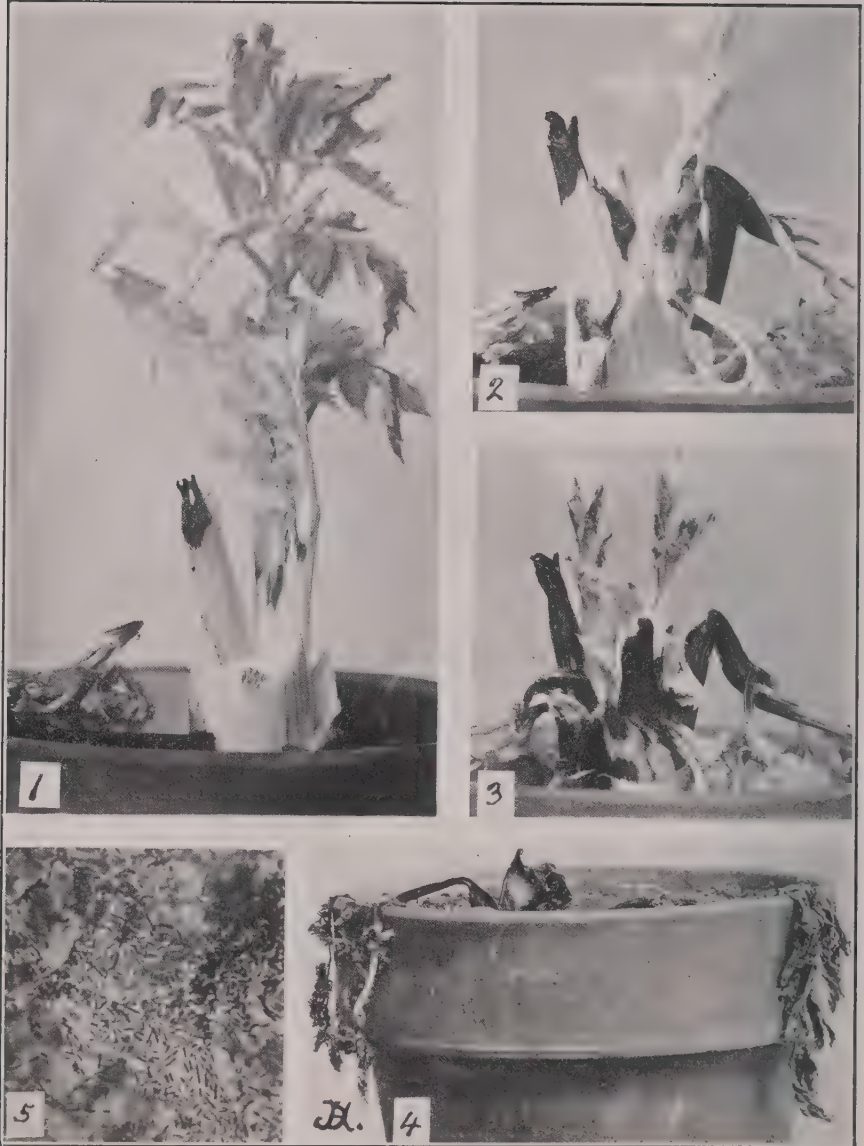
Spraying with insecticides is helpful indirectly, as it tends to keep in check the insects, slugs, caterpillars, etc., which are one of the most common means of spreading the disease from one plant to another.

As a rule the best method to adopt in dealing with a plant affected with bacterial soft rot, is to carefully remove and burn it. Insects, garden tools, etc., coming in contact with it will spread the disease to the plants with which they come in contact later.

Again, if affected plants are allowed to remain on the ground, they contaminate the soil with the organisms of the disease to such an extent as frequently to cause the disease to become established in the succeeding crop of any plants which are susceptible to the disease, but particularly plants of the same species.

Some time ago we received for examination a box of rotting, half-developed turnips, from a farmer who said that five per cent. of his crop were similarly affected. Upon enquiry we found that the affected ones were growing on soil on which turnips had been grown the year previous, and 25 to 30 per cent. of these having been affected with the same rot, had been allowed to remain on the ground at harvest time, and later were ploughed in. It was evident that the soft rot bacilli from the diseased turnips had remained alive in large numbers in the soil, and that many of the turnips of the subsequent crop had been inoculated with these bacteria during cultivation, and possibly by insect attack also, see page (56). The hoe or the teeth of the cultivator would get contaminated from the soil, and accidental wounding of a turnip with such an implement would result in the inoculation of the turnip with the germs of the disease.

Another man sent a head of celery for examination, which we found to be suffering from the bacterial soft rot in the young growing tips. In reply to our enquiries he sent word as follows: "I had celery on this ground two years ago, and the row that was where the rot is worst now was so bad then that I lost all; but only that row was affected. This year two rows had it, but one a great deal worse than the other. There were five rows in this patch, all planted about the same time. The healthy rows matured



Bacterial Soft Rot of Celery. (Original).

1. Artificial needle inoculation of pure culture of *Erw. carotovora* (isolated from rotting cauliflower) into the young and vigorous growth of celery. Five days after inoculation, kept at 25°C.
2. Same as Fig. 1, five days later.
3. Same as Fig. 1, ten days later.
4. Same as Fig. 1, three weeks after inoculation, showing complete collapse of plant.
5. *B. carotovorus*, the vegetable soft rot bacillus, between the cells of rotting celery tissue (x 1000 di.).

away ahead of the two which were diseased." Here it is evident that the soft rot bacteria had remained in the soil for two years, and that cultivation had spread the bacilli to some extent through the soil, as on the second occasion that celery was grown on that patch the plants in two rows developed the disease.

The writer had under observation a garden where turnips and carrots were both affected with the bacterial soft rot. The affected plants were not removed, but were dug in. The next year tomatoes were planted on the same ground. The disease did not develop in the growing plants, as care was taken not to wound them. However, about 60 per cent. of the fruit became affected before it was fully ripe. The affected specimens were either those that were in contact with the soil or had been bitten by slugs. The soft rot bacteria, which cannot penetrate through the sound skin of a tomato, found entrance through the slug bites or through the weakened skin that had been in contact with the soil.

Therefore, in order to prevent losses from bacterial soft rot of plants, remove and burn affected plants, or parts of plants, as soon as observed; be careful during cultivation not to wound plants, and keep caterpillars, slugs, biting and sucking insects in check. Affected plants should never be put on the compost heap or manure pile.

When harvesting and storing turnips, cauliflower, cabbage, celery, tomatoes or other vegetables from crops in which the disease has been present, great care should be taken not to include any specimen that shows the slightest appearance of the disease, or to smear the healthy specimen with the soft rotted parts of diseased specimens. If these precautions are neglected, the disease is liable to establish itself and spread more or less rapidly through the entire crop stored.

FUNGICIDES

BORDEAUX MIXTURE

The principal fungicide used for vegetables is Bordeaux mixture. Lime sulphur, sulphur dust and copper-lime dust are also used with good results in the control of some diseases. Two formulae are commonly used in the preparation of Bordeaux for spraying vegetables. (1) Bluestone (copper sulphate) 3 pounds, hydrated lime or fresh stone lime 6 pounds, water 40 gallons; (2) bluestone 4 pounds, hydrated lime or fresh stone lime 8 pounds, water 40 gallons. Hydrated lime is the more convenient form to use as it does not require slaking. It can be purchased in 50 pound paper sacks and it is easily stored. If left exposed to the air however, it becomes worthless, so keep it in tightly fastened paper bags in a dry place.

To prepare Bordeaux mixture dissolve the bluestone, then nearly fill the tank with water. Add the proper amount of dissolved bluestone. Then while the engine is running add the hydrated lime or slaked stone lime and agitate the mixture for about 5 minutes. If a hand outfit is used agitate by pumping the liquid back upon itself for 5 minutes.

N.B.—The easiest way to dissolve bluestone in the crystal or lump form is to place 40 pounds of it in a bag and suspend this in a barrel containing 40 gallons of water, in such a way that the bottom of the bag sinks only three or four inches below the surface of the water. Leave over night and in the morning all will be dissolved. One gallon of the liquid will now

contain one pound of bluestone. Small quantities can be dissolved readily by stirring in boiling water. Granulated bluestone dissolves very readily. If the desired amount is placed on a burlap screen over the opening in the tank it will dissolve while the water passes through it to fill the tank.

RESIN FISH OIL SOAP

Resin Fish Oil Soap is used with Bordeaux when a sticker is required to make the fungicide adhere better to the foliage. Three pounds of the soap are used with each 40 gallons of the Bordeaux. The soap is first mixed with water, using 1 gallon of water for each pound of soap. Hot water is preferable to cold water.

DUSTS

There are two classes of dusts, (1) finely ground sulphur, and (2) finely powdered bluestone combined with lime. Either of these can be secured with a poison added.

FORMALIN

Formalin is a clear liquid disinfectant. It is a 40 per cent. solution of formaldehyde gas in water. It is sold under the name of formalin and formaldehyde. It can be purchased in a drug store by the pound (16 ounces) or by the pint (20 ounces). It is important that the purchaser whatever name he buys it under, secures a solution of full strength, at least not less than 38 per cent. The solution should be kept in a well corked container and away from the frost. Formalin when diluted with water is not a dangerous poison although a weak solution will make the eyes smart and a strong solution will harden the skin temporarily.

CORROSIVE SUBLIMATE (MERCURIC CHLORIDE)

Corrosive sublimate may be obtained from any druggist. This is a deadly poison and should be so labeled and kept out of the way of children and stock. It is sold as a powder or in the form of tablets one of which dissolved in a pint of water gives a solution of the strength of 1 part by weight of corrosive sublimate to 1000 of water. It is not very readily soluble and hot water should be used to dissolve it. It corrodes metal and therefore should be mixed in wooden or earthen vessels. It is an excellent disinfectant but even in dilute solutions it is deadly poisonous. Great care therefore must be used in handling it. Potatoes disinfected with it should never be used as food for man or beast and vessels which have contained it should be thoroughly washed with hot water before they are used for any other purpose.

SOIL STERILIZATION

Many destructive insect and disease pests live over from crop to crop in the soil particularly in greenhouses. In order to get rid of these, soil sterilization becomes an important factor in the production of greenhouse crops. On many occasions the sterilizing is not thoroughly done, all parts of the soil may not be treated, or if treated, the soil is often re-infected

with untreated soil being carried in on contaminated boots or on dirty tools either from the outside or from another greenhouse. If the soil becomes contaminated after sterilizing, the disease usually develops more rapidly than it would if no sterilizing had been done.

There are two methods of sterilizing soil, one by using formaldehyde or other soil disinfectants, and the other by using steam. The steaming is preferable as it is more thorough, gives better control of nematodes, and kills the weed seeds present. Steaming may also improve the condition of the soil by liberating certain salts that were in the ground but were not in an available form for the plant. In rare cases however, the crop following steaming is poorer than that previous to steaming as toxic substances which are harmful to growing crops may be liberated during the steaming. All seed beds and greenhouses are not equipped for sterilizing with steam and hence formaldehyde or some other disinfectant must be used.

FORMALIN

Use 1 pint of formaldehyde to 10 gallons water and by means of an ordinary sprinkling can apply this solution at the rate of 1 gallon to 1 sq. ft. of soil. If the soil will not absorb 1 gallon per sq. ft. make the solution stronger so as to get a pint of formalin on about 10 sq. ft. It may be necessary to use a pint of formalin to 6 gallons of water and then add the 6 gallons to 10 sq. ft. of soil.

Dig up the soil before treating and as soon as sufficiently dry after treating dig up again. Do not set out any plants or sow any seeds for at least 10 days after treating. If the soil is light and likely to dry out quickly, it is advisable to cover it for a day or two after treating, using canvas, boards, etc. Formalin treatment will not control nematodes but it may check them to some extent.

STEAM

Sterilizing the soil with steam is the best method that can be used. As stated above it not only destroys insects and disease organisms but it also kills weed seeds. The soil should be fairly loose when steamed and no large lumps. It should not be too wet as it requires much more heat to raise the temperature of wet soil. Various methods are used in steaming the soil some of which are as follows:

1. *Inverted pan.* For outside seed beds or for small greenhouses where there are no posts in the seed bed and where nematodes are not giving trouble, this method gives good results. A pan 6 ft. x 12 ft. and 8 inches deep made of No. 16 galvanized iron reinforced with angle iron is a convenient size of pan to use. In order to move the pan a handle or large ring should be attached to each corner of it. The pan should be held in place by stones or bags of sand and the soil banked around its edges. The steam should enter in such a manner that it is not forced directly into the soil at the point of entrance. The steam may enter at the central part of the pan and a "T" be fitted on the inside so as to force the steam each way, or the steam may enter at one end of the pan, or a bent pipe may be used which will pass underneath the edge of the pan and the open end come above the surface of the soil underneath the pan. The pan is connected to the boiler by means of piping and heavy rubber hose. The boiler should have a capacity sufficient to discharge steam at 80 to 100 lbs. pressure and the pan left in position for 30 min. or longer. The steaming should be con-

tinued until a potato about 4 inches deep in the soil is cooked. When the pan is moved forward to a new position it should be placed so that it will slightly overlap the area already sterilized. It is advisable to cover the place that has been sterilized with a heavy canvas in order to retain the heat and secure better penetration. Care must also be taken when moving the pan that no dirt be carried from the unsterilized area to that which has been sterilized. A threshing engine that is in good condition may be used for sterilizing with the pan system.

2. *Steam harrow.* The steam harrow is shaped somewhat like an ordinary field harrow. It is composed of hollow iron cross pieces and hollow teeth about 8 inches in length. At the lower end of each tooth is a small hole to allow the steam to escape. The whole harrow is covered with a heavy canvas so as to prevent the escape of steam. The teeth are forced to their full depth into the soil and the steam is passed into the cross bars from an attached pipe and escapes at the point of the teeth. As most of the steam escapes up the side of the teeth and does not penetrate the soil to any great extent the steam harrow gives no better results than the inverted pan.

3. *Steam pipes.* A number of pipes having a diameter of $1\frac{1}{2}$ or 2 inches are used. A row of holes $\frac{1}{8}$ " diameter and 6" apart is drilled along one side. These pipes are placed in the soil in parallel trenches with the holes on the underside and with one end connected with a cross pipe which is joined to the steam line. The trenches are then filled in and steam passed through the pipes. This method however, is not very satisfactory as the trenches have to be dug and the pipes changed before and after each steaming. If left in the soil the holes are likely to become plugged and the pipes rusted.

4. *Tile.* In the larger greenhouses and where nematodes cause trouble, steaming through tile is the most satisfactory method of soil sterilization. Parallel trenches are dug and 3 inch or 4 inch tile are laid so that the top of the tile will be about 12 to 15 inches below the surface of the soil. They should be deep enough so that when the soil is being dug up there is no danger of breaking the tile. The centres of the trenches may be from 18" to 2' apart, depending on the nature of the soil. If the soil is loose and open the tile may be placed deeper and a little further apart than in soil of a heavier type. The length of the rows of tile also depends to some extent on the capacity of the boiler to be used in steaming. Four or five or more short rows of tile may be connected at one end by a cross pipe and steam passed into all of these at the same time, or tile may be laid the length of the house and steam passed into only one or two rows at the same time. Where this is done steam may enter at the middle of the row and pass each way in the tile. Where a large boiler has been used satisfactory results have been obtained in houses 300 ft. long with steam entering the tile in the middle of the row going 150 ft. each way. However, it is better to have shorter rows of tile and a few rows connected with a cross pipe as the temperature of the soil rises at a more uniform rate throughout the area that is being steamed. When rows are long one end frequently heats up faster than the other, hence a loss of steam. Under certain conditions tile may be laid in rows running crosswise in the house rather than lengthwise.

In order that a thorough job of sterilizing may be done the outer rows of tile should be laid close to the side walls and the ends of the rows of tile should be brought close to the end walls. The tile may be connected to the steam line in different ways. When a few short rows are to be ster-

ilized at once, a two or three inch pipe may be placed in the ground along the ends of the rows with a "T" at the end of each tile and a short piece of piping running into each tile. Another short piece of piping is fitted into the middle of this and extends to the surface of the ground where it can be conveniently coupled up with the steam line. When steaming is completed a cap may be screwed on this pipe to keep out the dirt. If the steaming is to be done through long individual rows of tile it is preferable to have the steam enter at the middle of the row and pass each way. This can be done by having a "T" arranged so that each end fits into the tile and the central part comes to the surface of the ground. When steaming is completed in one row a cap may be screwed on the end of the piping that comes to the surface of the ground and it can then be left for future use.

When the steam is passed through a row of tile 100 ft. or more in length the opposite end of the tile should be fitted with a small pipe coming to the surface of the soil. This should be left open until the steam begins to escape freely and then closed. This is particularly necessary in heavier types of soil in order to allow the cold air in the tile to escape and thus ensures a more even distribution of steam. In loose open soils the cold air seems to escape more easily and hence it is not so necessary to have the far end of the tile fitted with a small pipe.

Steam sterilizing by means of tile should be done during the summer months. Results are more satisfactory and it is a much greater saving on fuel than when done in winter months. If done during the winter months the soil should be covered with blankets, canvas, etc., otherwise it is difficult to heat the surface.

Steam may be carried from the boiler to the tile through pipes used for heating but usually it is more satisfactory to run a direct line using 2 or 2½ inch pipe, from the boiler to the tile. This pipe line may be connected with the piping in the soil by means of an ordinary union or by using a piece of heavy rubber hose.

When starting to steam one should have on hand one or two good thermometers that will stand a temperature of over 212°F (boiling point) and protected by a case so they can be inserted in the soil. Such thermometers are expensive but are necessary if one is to be sure of a thorough job and at the same time not waste time and fuel.

The length of time required to sterilize any soil depends on the capacity of the boiler and the area that is being sterilized. A boiler with 100 H.P. capacity and carrying 75 to 80 lbs. of steam should sterilize an area the width of two rows of tile 100 ft. long in two or three hours. The larger the area the longer it will take. If the steaming is continued for an hour or even less after the temperature of the soil between the tiles has reached 200°F, the results ought to be satisfactory.

Soil that is to be used for potting purposes may be sterilized either by making use of the inverted pan or by building a narrow box with pipes fitted along both sides. On the side of the pipes next the centre of the box should be holes ⅛" diameter and about 6" apart. The box may be filled with soil, a tight fitting lid put on and steam passed through the pipes.

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